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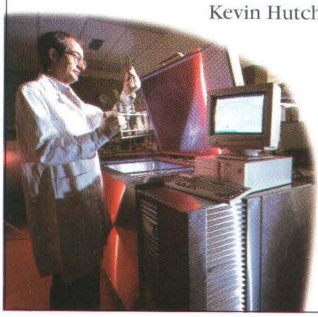

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Cover: O.V. Mooney, "Forester" and "Nature's gentleman". See *An Appreciation* (page 140).

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The main activities of the Society include the organisation of symposia, field meetings and study tours on forestry topics, and the publication of *Irish Forestry*, the Society's journal, and *The Irish Forester*, its quarterly newsletter. The Society also organises forestry shows and exhibitions, and has published *The Forests of Ireland* and *Forest Images – Father Browne's Woodland Photographs.*

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Guidelines for Submissions

Authors are to observe the following guidelines when submitting material for publication in *Irish Forestry*:

- One complete copy must be submitted in typescript. Correct spelling, grammar and punctuation are expected. Nomenclature, symbols and abbreviations to follow established conventions, with the metric system used throughout.
- A computer disc containing text must be submitted. If applicable, a second disc containing computer generated tables, graphs and illustrations is also required. In both cases, clearly indicate the computer package used.
- Authors submitting scientific papers are requested to indicate whether they wish their material to be subjected to peer review. Papers submitted for peer review should include an abstract (max. 150 words) and a list of up to six key words before the main body of text. For general papers, a summary (max. 250 words) is required.
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  Gallagher, G. and Gillespie, J. 1984. The economics of peatland afforestation. *In:* Proc. 7th Int. Peat Conf. Dublin. Vol. 3:271-285.
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  Forestry Abstracts may be used as a guide in the abbreviation of journal titles.
- Communication relating to submissions will be made with the senior author. Prior to printing, a draft will be returned to the senior author for final proofing. Authors are requested to confine alterations at this late stage to the correction of typing errors.
- Submission of a paper is understood to imply that the paper is original and unpublished and is not being considered for publication elsewhere.

The above guidelines are designed to facilitate the speedy processing of material submitted for publication in *Irish Forestry*. Inadequate adherence to these guidelines may result in material being returned to the author for redrafting.

EDITORIAL

Since its first appearance in 1943, *Irish Forestry* has led the way as the forum for published research and discussion into forestry in Ireland. Each editor has in turn endeavoured to provide Society members – Ireland's professional foresters – with the latest information on research and development in our chosen field. In many ways, a quick glance at the contents page of any particular issue of *Irish Forestry* over the past half-century provides the reader with a brief but insightful snapshot into developments and initiatives current at that time. Along the way, some of these were tried and failed, while others succeeded and went on to become standard practice. Taken together, however, all have brought forestry in Ireland to its current state as a renewable landuse not only capable of supporting an ever-growing processing industry, but also capable of sustaining a wide range of additional roles – from landscape enhancement and rural development to increased biodiversity and carbon sequestration.

Just as the contents of earlier issues of *Irish Forestry* offered a flavour of what was current at that time, so too do the contents of this issue. Contained within are papers relating to all stages of the wood chain, from species and provenance selection and the effect of early formative shaping on broadleaf quality, to a review of the impact of wind on established forests and an exploration of the potential application of chemical modification to Irish timber. Also included are a range of papers dealing with issues which are perhaps not directly related to the wood chain, but which nevertheless reflect the wider role forestry in Ireland is now being called upon to fulfil. These include studies of avian biodiversity and nutrient dynamics in Irish forests, a proposed landscape planning and design model, a review of the potential of western red cedar as a candidate for furthering species diversity, an example from Nepal of local stakeholder participation in forest management, and a study of Ireland's tree collections, which play an important role in providing forest recreation and nurturing a public understanding of and a sense of wonder in trees.

This writer believes that the diversity of material now appearing in *Irish Forestry*, and indeed the diversity of professionals now contributing on a regular basis to the journal, reflect a coming-of-age for forestry in Ireland, not only in terms of its status as the fastest growing landuse on the island, but also in terms of its multi-functional role and ability to deliver a huge range of benefits, economic, social and environmental. This achievement is a legacy handed down to us by our predecessors, and hopefully we can continue their vision and belief in the future which underpin the very nature of forestry in all its aspects. Perhaps our biggest failing, however, is our inability sometimes to communicate this vision and belief to other professionals and to the general public - a weakness all too apparent when one reads the recent policy paper on forestry from the Heritage Council. Numerous initiatives, some originating from the forestry sector and others from other quarters, are, however, beginning to foster a tree culture in Ireland. These include the Millennium Native Woodlands Initiative, the Tree Register of Ireland, Trees of Time and Place, the Forest of Belfast and Tree Day, to name-check but a few. As well as achieving their own specific aims and objectives, all of these combine to provide a context for the development of forestry in Ireland. Meanwhile, forestry has become in recent years a multi-professional discipline, a landuse led by the professional forester but in close co-operation and consultation with a huge range of other interests and disciplines.

These are indeed exciting times for Irish forestry. Perhaps future members of the Society will review current issues of the journal and reminisce on the time when forestry in Ireland came down from the mountains and onto the lowlands, both physically and in the minds of the people of this island.

Submissions to *Irish Forestry* are welcomed and will be considered for publication.
The attention of contributors is drawn to "Guidelines for Submissions".

Submissions to be addressed to:

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An assessment of avian biodiversity and opportunities for enhancement in Ireland's forests: preliminary results

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Abstract
Forest expansion in Ireland has led to concern for the characteristic plant and animal communities associated with the planted land. If carefully planned, however, forestry may provide opportunities for conservation and enhancement of biodiversity. This study sets out to provide systematic data on bird assemblages in Irish plantation forests, and to suggest ways in which the biodiversity, as represented by birdlife, might be enhanced. Preliminary data are presented on the general bird assemblages of 'mature' (pole-stage) forests in southwest Ireland during spring/summer, autumn and winter 1996/97, and on bird/habitat relationships. A total of 38 bird species was recorded within the 20 forest compartments studied, with goldcrest (*Regulus regulus*) being the most abundant and widespread. Some species showed marked seasonal variation in forest usage. Habitat factors which showed a positive relationship to bird species richness and/or bird density included, on varying scales, the number of broadleaf species present, proximity to the forest edge, and the amount of undergrowth. Some bird species also showed evidence of association with particular species of conifer.

Keywords: birds, conifers, tree species, goldcrest, edge

Introduction
Forestry is an important land use in Ireland, and is based primarily on exotic conifers grown over relatively short rotations. With a projected annual planting area of 20-25,000 ha/year (Anon., 1996), the future development of the forestry sector will lead to increased areas of the landscape being afforested, and this will have implications for biodiversity and conservation. Increasing afforestation has led to concern for the characteristic ecological communities associated with the planted land (e.g. Ratcliffe, 1986 & 1990; Nature Conservancy Council, 1986; Hickie *et al.*, 1993). Much of this concern has focused on birds and on fishlife in rivers draining forested catchments. Forest ecosystems can, however, be rich in biodiversity, ranging from microbial to fungal, plant and animal communities. Thus, forest expansion, if carefully planned, may provide opportunities for conservation and the enhancement of biodiversity.

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A project is underway at University College Cork, investigating the enhancement opportunities for birds in forestry and for fish in forested catchments at a range of study sites in Munster (Lehane *et al.*, 1997). In this paper, preliminary data and analyses on bird communities in plantation forests in Munster are presented and discussed.

Bird communities utilise plantation forests at each stage of the forest cycle. Much data has been collected on forest birds in Britain and reviewed by Avery and Leslie (1990) and Petty and Avery (1990) for terrestrial species. Data on aquatic birds in forested catchments have been presented by O'Halloran *et al.* (1990), Ormerod *et al.* (1991) and Smiddy *et al.* (1995). In the case of terrestrial birds, one the strongest criticisms of plantation forestry has been levelled at the loss of breeding moorland habitat for birds such as golden plover (*Pluvialis apricaria*) and red grouse (*Lagopus scoticus*), particularly in Britain (Petty and Avery, 1990). There can also be impacts on other breeding species such as raven (*Corvus corax*) and raptors like merlin (*Falco columbarius*), through the loss of open country used for feeding, even though forests may in some cases provide new nesting habitat (e.g. Parr, 1991).

In Ireland, few published data are available on breeding birds of moorlands. Examination of the most recent data (Gibbons *et al.*, 1993) suggests, however, that it is unlikely that the expansion of forestry will have as significant an impact on moorland birds as that in northern Britain, as fewer individuals or species, particularly of wading birds, are found in equivalent Irish habitats. One of the main reasons for the scarcity of breeding wading birds on many Irish moorlands, particularly in the southern half of the island, may be that these species are at the edge of their breeding ranges (Cramp, 1983). There will, however, be regional differences, the general trend being for an increase in species richness of moorland species from south to north (cf. Avery and Leslie, 1990). Another important factor is that, for historical and biogeographical reasons, the bird species pool in Ireland is relatively small, with few true woodland species (Wilson, 1977; Hutchinson, 1989). Therefore, the impact, positive or negative, of afforestation is likely to be different here than that in Britain. Forest plots also differ, being on average smaller than those in Britain (Heritage Council, 1997) and thus having a relatively greater edge-length, perhaps providing new opportunities for species. The planting of trees in some areas, therefore, may lead to increased opportunities for biodiversity, through the provision of new breeding, feeding and roosting habitats for birds.

This study sets out to collect systematic data on bird assemblages in Irish plantation forests, and also to suggest ways in which biodiversity, as represented by birds, might be enhanced. Most of the work focuses on conifer plantations, which still dominate both semi-state and private planting. New plantings of broadleaf trees are, however, expected to increase, particularly on higher quality land planted by the private forestry sector (Anon., 1996), and further work may be needed to address the potential in this area.

The project began in autumn 1995 and will continue until 1999. The data presented here cover part of the first year's fieldwork, focusing on assemblages and habitat relationships of birds in pole-stage forests during the breeding season, autumn and winter. The results are preliminary, and further analysis is underway. Other phases of the project will examine the influence of tree age, and the size and shape of forest stands, on birds. Sample surveys of some individual species (nightjar (*Caprimulgus europaeus*) and long-eared owl (*Asio otus*)) are also underway.

Methods

Selection and location of study sites

Forests owned by Coillte are being used to provide a representative pool of study sites, by agreement with staff in the company's Cork and Kilkenny regions. The sites were selected following examination of the forest inventory data. For the 1996 field season, 20 sites (compartments) were selected, focusing on randomly selected sub-compartments containing at least 10 ha of a particular age class (30-45 year old trees) of selected conifer species (Table 1). The compartments studied were mainly 15-25 ha in area, with a range of 11-31 ha.

Table 1. *'Target' tree species for the 1996/97 fieldwork.*

Sitka spruce (*Picea sitchensis* (Bong.) Carr.)
Norway spruce (*P. abies* (L.) Karst.)
Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco)
Noble fir (*Abies procera* Rehd.)
Lodgepole pine (*Pinus contorta* Dougl.)
Scots pine (*P. sylvestris* L.)
Japanese larch (*Larix kaempferi* (Lamb.) Carr.)

Marking of sampling points

For each compartment, a 50 m x 50 m grid was traced onto a scaled enlargement of the relevant Coillte forest inventory map, starting from a randomly selected corner (e.g. NE) of the compartment boundary. Points were marked at the intersections of the grid, and those greater than or equal to 30 m from the compartment boundary were numbered in sequence from NE to SE. For the 'main' tree species in the compartment, i.e. the species for which the compartment was selected, an initial random selection of numbered points was made, with a criterion that the points were at least 100 m apart and at least 30 m from sub-compartments containing other tree species. Once these points had been selected, a random selection from the remaining available points was made.

In the field, the selected points were located using a compass, tape and a cord marked at intervals. Each point was marked and numbered with a small plastic tag, painted fluorescent yellow. The approach to each point, along a north-south or east-west line, was marked at frequent intervals with a small piece of coloured twine.

Collection of bird data

Counts were made in 20 forest compartments at a total of 200 points (the maximum number of points possible, given randomisation and the restrictions set out above). Using the methodology described by Bibby *et al.* (1985 & 1992), birds seen or heard within a 30 m radius of each point were noted separately from birds seen or heard beyond that radius and from birds in flight above the canopy. By taking into account differences in the detectability of different species (Bibby *et al.*, 1992), this method allows estimation of bird densities. Data were collected over a 10-minute period at each point on each count-date. For the analyses presented here, bird densities and species composition were based on the second 5-minute period of each 10-minute count (for comparability with British studies by Bibby *et al.* (1985 & 1992)), while bird/habitat relationships were assessed using 10-minute counts or the full site-visits.

Spring/summer (breeding season) data collection

Counts were made twice at each point in each forest compartment, once between mid-April and mid-May, and once between mid-May and mid-June, 1996, to allow for possible seasonal changes in bird detectability and for the late arrival of migratory species. For each point and species, the highest count from the two dates available was used for analysis, following Bibby *et al.* (1992).

Autumn and winter data collection

Points were visited once in autumn (September-October 1996) and up to twice in winter (November 1996 - February 1997), to identify possible seasonal changes in the use of plantation forests by birds.

Collection of habitat data

Standardised data on vegetation were also collected at the study sites for analysis of habitat/bird assemblage relationships. In the first year's study, data were collected on the tree species present, and their relative abundance, within a 30 m radius of each sample point and within each compartment as a whole. Other parameters recorded included percentage ground cover of different vegetation types (e.g. bramble (*Rubus* spp.)) at each point. In this paper, results of a number of univariate analyses (including simple regressions) are presented. A more detailed presentation of habitat variables and results will be provided elsewhere.

Results

Overall pattern: spring and summer

In total, 31 species of birds were recorded within compartment boundaries during the breeding season (Table 2). A number of additional species were recorded in flight only, or detected outside the compartment boundaries, e.g. singing from adjacent hedgerows.

Eight species were recorded in all compartments, with goldcrest (*Regulus regulus*) being the most abundant species, followed by robin (*Erithacus rubecula*) and chaffinch (*Fringilla coelebs*). The average density of birds was estimated at 12.1 birds/ha, of which approximately half were goldcrests. Figure 1 compares the species composition of passerines (excluding species larger than jay (*Garrulus glandarius*)) recorded in this study with data from limited previous studies of breeding birds in Irish conifer plantations. The relative abundance of goldcrests in conifer forests in Ireland is much greater than in broadleaf forests (Figure 1). Studies of 'mature' conifer forests in Scotland found a broadly similar species composition to this study, again with a preponderance of goldcrest. Note that comparisons are based on relative (rather than absolute) densities in Figure 1, due to possible methodological biases in different studies.

Autumn and winter

There were seasonal differences in the utilisation of forests by birds, although some species were widespread during all seasons. A total of 32 species was recorded in November-February 1996/97, with 23 species recorded at a smaller sample of sites in autumn (Table 2). Some species were absent in winter, notably summer visitors such as spotted flycatcher (*Muscicapa striata*). Other (resident) species, such as woodpigeon (*Columba palumbus*) (Figure 2) and song thrush (*Turdus philomelos*), occurred in a higher propor-

Table 2. *Bird species recorded in 20 coniferous forest compartments (mainly 30- to 45-year old trees) in Munster during standardised breeding season, autumn and winter surveys in 1996/97. Species recorded only in flight above the forest canopy, or outside compartment boundaries, are excluded. The list is derived from two morning visits to all 20 compartments in April-June 1996, one visit to nine compartments in September-October 1996, and one or two visits to 19 compartments in November 1996 - February 1997.*

	Apr-Jun	*Sep-Oct*	*Nov-Feb*		*Apr-Jun*	*Sep-Oct*	*Nov-Feb*
Grey heron (*Ardea cinerea*)	+	+	+	Long-tailed tit (*Aegithalos caudatus*)	+	+	+
Mallard (*Anas platyrhynchos*)			+	Coal tit (*Parus ater*)	+	+	+
Sparrowhawk (*Accipiter nisus*)	+		+	Blue tit (*P. caeruleus*)	+	+	+
Kestrel (*Falco tinnunculus*)			+	Great tit (*P. major*)	+	+	+
Moorhen (*Gallinula chloropus*)	+			Treecreeper (*Certhia familiaris*)	+	+	+
Pheasant (*Phasianus colchicus*)			+	Jay (*Garrulus glandarius*)	+	+	+
Woodcock (*Scolopax rusticola*)	+		+	Magpie (*Pica pica*)	+	+	+
Woodpigeon (*Columba palumbus*)	+	+	+	Rook (*Corvus frugilegus*)			+
Wren (*Troglodytes troglodytes*)	+	+	+	Hooded crow (*C. corone*)	+	+	+
Dunnock (*Prunella modularis*)	+	+	+	Raven (*C. corax*)	+		+
Robin (*Erithacus rubecula*)	+	+	+	Chaffinch (*Fringilla coelebs*)	+	+	+
Stonechat (*Saxicola torquata*)	+			Greenfinch (*Carduelis chloris*)			+
Blackbird (*Turdus merula*)	+	+	+	Goldfinch (*C. carduelis*)			+
Song thrush (*T. philomelos*)	+	+	+	Siskin (*C. spinus*)	+	+	+
Redwing (*T. iliacus*)			+	Redpoll (*C. flammea*)	+	+	+
Mistle thrush (*T. viscivorus*)	+	+	+	Crossbill (*Loxia curvirostra*)	+		+
Blackcap (*Sylvia atricapilla*)	+			Bullfinch (*Pyrrhula pyrrhula*)	+	+	+
Chiffchaff (*Phylloscopus collybita*)	+	+					
Willow warbler (*P. trochilus*)	+	+					
Goldcrest (*Regulus regulus*)	+	+	+	Number of species (overall total 38 species)	31	23	32
Spotted flycatcher (*Muscicapa striata*)	+						

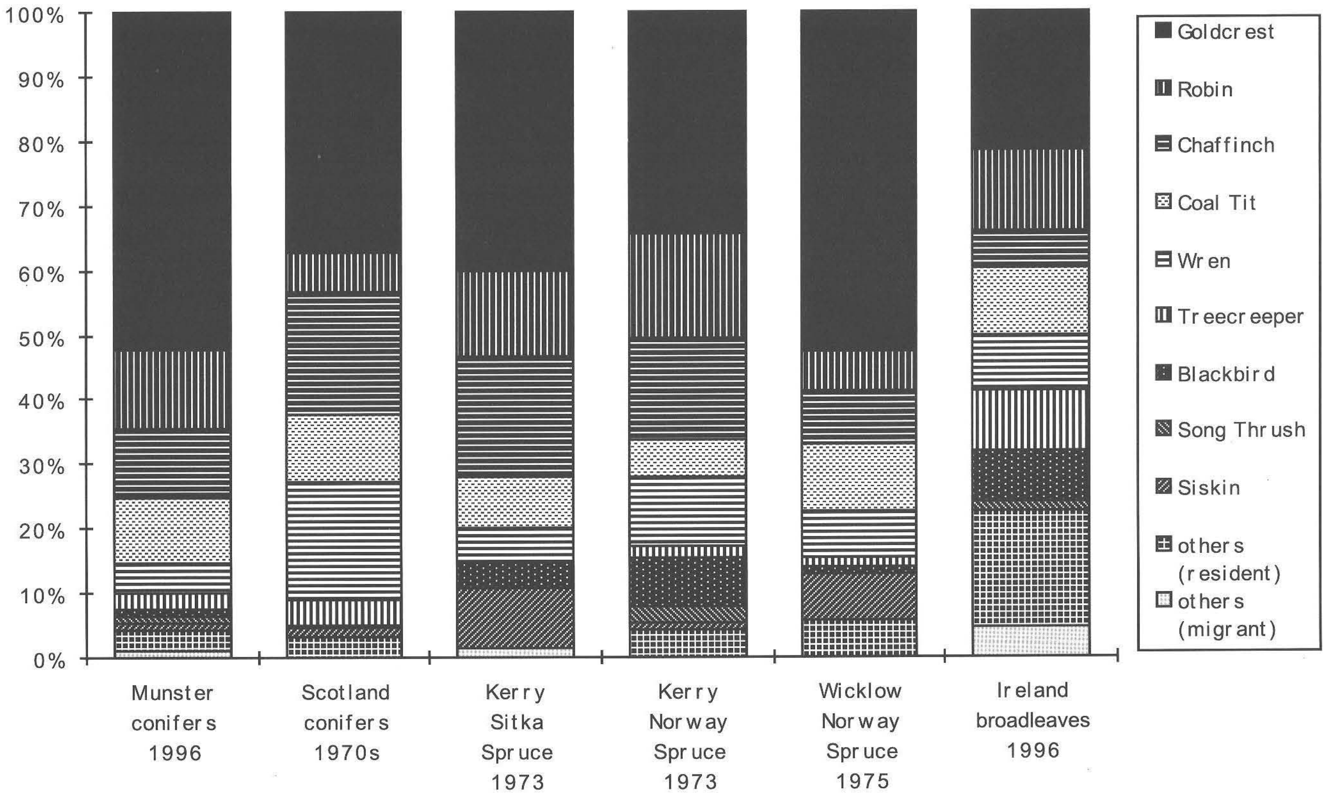

Figure 1. *Percentage composition of the passerine bird assemblages recorded in various 'mature' forests in the breeding season. Sources: Munster conifer and Irish broadleaf forests (this study); Scotland (Moss, 1978a & 1978b); Kerry (Batten, 1976); and Wicklow (Wilson, pers. comm., 1996).*

tion of compartments in spring and summer. Some resident species, notably blue tit (*Parus caeruleus*) (Figure 3), and species whose resident populations are augmented by winter visitors, notably woodcock (*Scolopax rusticola*), were, however, much more widely recorded in winter. Some species present in winter were totally absent from the study sites during the breeding season. These not only included winter visitors such as redwing (*T. iliacus*), but also some residents, such as greenfinch (*Carduelis chloris*) (Walsh *et al.*, 1999).

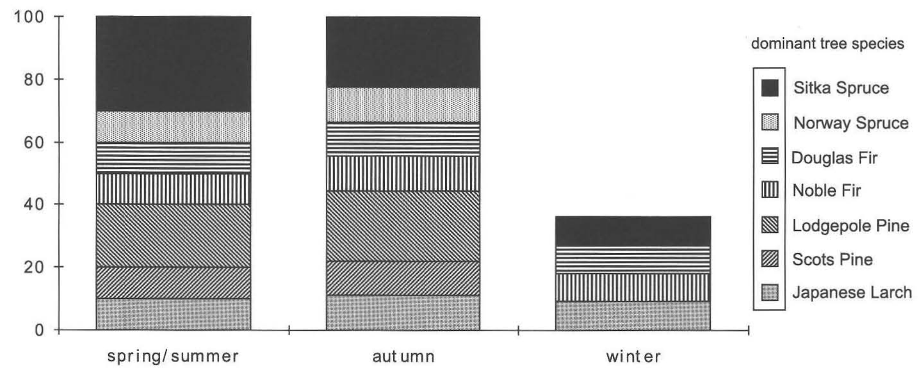

Figure 2. *Percentage occurrence of woodpigeon (*Columba palumbus*) in Munster forest compartments in different seasons, 1996/97 (based on two visits to 20 compartments in April-June, one visit to nine compartments in September-October, and two visits to 11 compartments in November-February).*

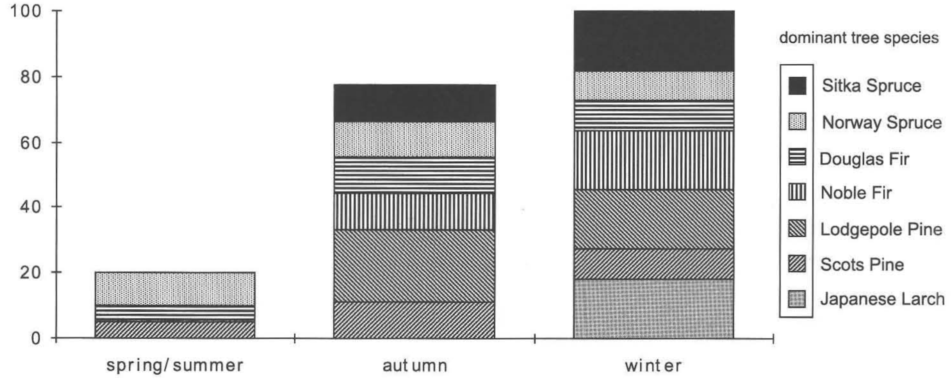

Figure 3. *Percentage occurrence of blue tit (*Parus caeruleus*) in Munster forest compartments in different seasons, 1996/97 (see Figure 2 for sample sizes).*

Influence of tree species

Preliminary analysis suggests that the greatest number of bird species in compartments were associated with Norway spruce (*Picea abies* (L.) Karst.) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), with fewer in Sitka spruce (*P. sitchensis* (Bong.) Carr.) and lodgepole pine (*Pinus contorta* Dougl.) during spring/summer. Broadly similar patterns were seen in autumn and winter. The possible influences of altitude or other factors (e.g. soil type, edge length or associated broadleaf trees) must, however, also be considered, and further analysis is underway.

There was a significant positive relationship ($r = 0.63$, $p<0.01$) between the number of bird species and the total number of tree species during the breeding season within a compartment. This relationship seemed to be explained largely by the number of broadleaf species (including shrub and understorey layer) within a compartment (R^2 x 100 = 62%, $p<0.001$). No significant relationship was found between the number of bird species and the number of conifer species at either the compartment (R^2 x 100 = 0.7%) or the point-count level.

For an initial analysis of tree species preference, a comparison was made of the frequency of occurrence of goldcrest and coal tit (*P. ater*), two of the most characteristic and abundant bird species of conifer plantations, at points where different conifer species predominated. Goldcrest occurrence varied significantly (chi-squared (df 6) = 39.72, $p<0.001$) in relation to tree species, with spruces and firs apparently favoured. Coal tits also showed a significant (chi-squared (df 6) = 12.6, $p<0.05$) variation in occurrence between different conifer species, apparently favouring lodgepole pine and Noble fir (*Abies procera* Rehd.).

Influence of distance from edge or rides

Approximately half of the points studied were within 50 m of a ride greater than 4 m in width, or an open space greater than 5 m x 5 m in area. During the breeding season, the points nearest such edges held, on average, slightly but significantly more species within a 30 m radius than points greater than 50 m from the edge ($d = 2.01$, $p<0.05$).

Influence of ground vegetation

Over the range of forest compartments studied, ground cover varied from almost bare (needles or moss with some brash) to extensive bramble cover. One bird species which appeared to benefit from the presence of brambles in this study was wren (*Troglodytes troglodytes*), numbers of which showed a positive relationship to the percentage bramble cover (Figure 4).

Discussion

As noted earlier, this paper is based on preliminary data collection and analysis, with results limited to 20 sites of a particular age class of tree. Further data on different age classes will give a more complete picture of species utilisation of plantation forests in Ireland. The authors also recognise that other factors such as altitude, soil type, availability of nesting sites, etc. have not been included in this analysis.

The most dominant bird species found in the Irish forests studied to date (Figure 1) are broadly similar to those found on agricultural land (Lysaght, 1989; Moles and Breen, 1995; Holt, 1996), with the exception of some additional forest specialist species and the absence of 'open-country' species such as skylark (*Alauda arvensis*). The species diver-

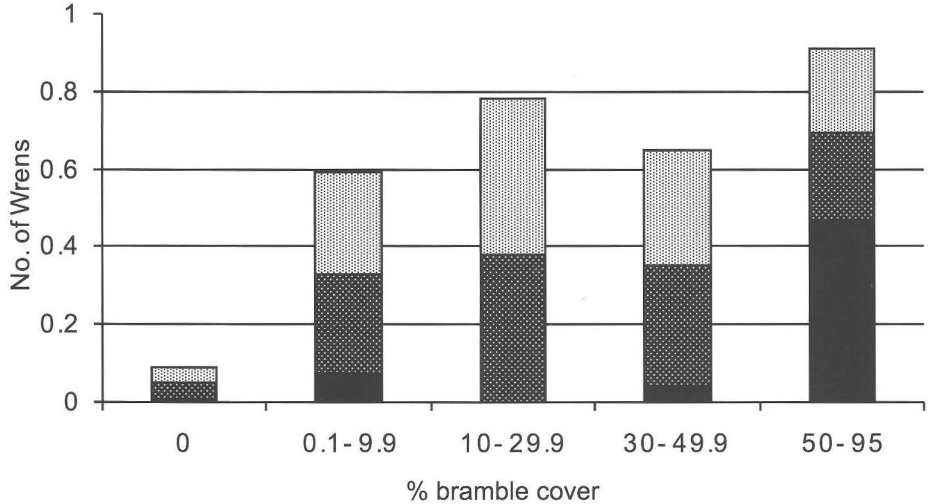

Figure 4. *Number of wren (*Troglodytes troglodytes*) recorded within a 30 m radius during breeding season in relation to the percentage bramble cover (based on the highest of two 10-minute counts at 200 points in Munster forests). Mean peak counts ± 95% confidence limits are shown.*

sity of conifer forests in Ireland may to some extent be limited by the species pool available for colonisation, rather than any intrinsic property of the forests themselves, though the size of the forests and distance from the edge may be important. Comparison of population densities between habitats, and between studies, is complicated by differences in methodology. Some tentative comparisons, particularly of species diversity, can, however, be made. For example, Lysaght (1989) recorded 33 breeding bird species on five farmland plots totalling 181 ha in Co. Limerick, with an average density of 2.7 breeding territories (5.4 breeding birds, excluding woodpigeon)/ha. The species total is broadly similar to the number of species 'using' the forest plots in this study (31 species recorded in 380 ha), with breeding densities apparently higher in the forest (12 birds or 6 territories/ha). In fact, species diversity of forested areas containing a range of tree age classes can be expected to show even higher species richness than this (Petty and Avery, 1990). Furthermore, the breeding diversity and density of birds on farmland may be reduced markedly where hedgerow availability is reduced (Moles and Breen, 1995). The conservation value of forested land relative to intensively farmed land may thus be greater than is generally appreciated.

Comparisons with the results of Batten (1976) and Wilson (pers. comm., 1996) in Irish conifer plantations (Figure 1) show a similar pattern for bird assemblages during the breeding season. In each case, goldcrest was the most abundant species, generally followed by robin, chaffinch, coal tit and wren. Bird densities recorded by these authors were within the range 10-18 territories (20-36 breeding birds)/ha. These figures suggest higher densities than those recorded in this study, although different methodology (territorial mapping versus point counts) and the wider range of tree species studied here, may account for at least some of these differences. The densities, however, of breeding goldcrests in these earlier studies ranged from 3.8 to 5.9 territories (7.6-11.8 birds)/ha, which are broadly similar to the overall estimate (6.1 birds/ha) recorded in this study.

The most obvious difference in results between this study and other studies of Irish broadleaf forests (Batten, 1976; Wilson, 1977; Nairn and Farrelly, 1991; Carruthers and Gosler, 1995) is that fewer goldcrests were recorded in broadleaves than in conifers. The studies of deciduous forests recorded a higher density of some resident species, notably blue tits and great tits (*P. major*) (for which few nest-holes are available in conifer forests), and also generally higher densities and diversity of migrant species than in 'mature' conifer forests.

The bird species composition in this study is also broadly similar to those for mature plantations in Scotland (Moss, 1978a & 1978b), although the latter studies recorded proportionately more wrens, possibly reflecting differences in ground cover. Research in Wales has concentrated on edges and deciduous patches in conifer forests (Bibby *et al.*, 1989), or on young re-afforested stands (Bibby *et al.*, 1985). In each case, a higher proportion of migrant birds was recorded than in older conifers in either Ireland or Scotland. Another phase of the current study is focusing on younger forests, and comparisons will be published elsewhere.

Interesting temporal differences in the avian usage of Irish conifer forests were noted, with some species apparently more widespread during the spring/summer (e.g. song thrush) and others in autumn and winter (e.g. blue tit). These temporal differences are in part explained by the nesting or feeding requirements of different species, which conifer plantations may not always provide during a given season. Also, dispersal of juvenile birds after the breeding season may lead to some species becoming more widespread. Another factor is that some species are less readily detectable outside of the breeding season. More obviously, seasonal differences also reflect migratory movements of some species. There are no comparable published Irish data for winter bird assemblages in conifer forests, although some relevant data have recently been published for western England (Donald *et al.*, 1997).

Some bird species of considerable conservation interest may rely exclusively, or heavily, on conifer plantations. Forestry practices may thus provide an opportunity to enhance the conservation status of such species. This is particularly true in the case of the crossbill (*Loxia curvirostra*), which has benefited greatly from increased afforestation and is now widely, if sparsely, distributed in Ireland. This species occasionally 'irrupts' in large numbers from continental Europe, and many of these birds remain to breed in Irish conifer plantations, which also maintain a pool of breeding birds between irruptions (Sharrock, 1976; Gibbons *et al.*, 1993). While mature stands are important habitats for crossbill, younger (mainly 1- to 10-year old) conifer plantations now appear to be the most important habitat of breeding nightjars in Britain, aiding their recovery from an earlier decline (Morris *et al.*, 1994). The nightjar is listed in the Irish Red Data Book (Whilde, 1993) as very rare, having declined markedly since the 1950s, with perhaps as few as 30 pairs breeding annually. Young forests may thus be of particular importance to the conservation of the species in Ireland.

Given the paucity of natural or semi-natural woodland in Ireland, conifer forests may also contribute to the conservation of common bird species. Although coal tits are abundant in Ireland, they represent a native subspecies (*P. ater hibernicus*) (Hutchinson, 1989) for which conifer plantations provide a favourable habitat, perhaps even a refuge, where competition with other tit species is reduced. Another example is song thrush, a species which has declined markedly in Britain (Thompson *et al.*, 1997). The widespread occurrence of this species in Irish conifer plantations may indicate that these forests could compensate in part for the loss of other breeding habitats.

Much has been written about the importance of edge effect in ecology and in forestry. The edges between vegetation types (ecotones) are generally more diverse in their flora and fauna than separate habitats (Pianka, 1974; Burgess and Sharpe, 1981). The preliminary data from this study suggest that there were more bird species near the forest edge, perhaps reflecting factors such as increased habitat diversity and light penetration, both of which influence food availability. Another phase of the ongoing project will study in more detail the possible influence of the shape and edge-to-area ratio of forest blocks.

This study provides some preliminary indications as to how Irish forests might be enhanced for avian biodiversity:

1. The species of conifer will influence the abundance of individual birds and species. The selection of tree species should therefore include consideration of a biodiversity component.
2. The number of broadleaf tree species (including shrubs or undergrowth) may influence the number of bird species. The inclusion of more broadleaves in planting could therefore improve bird species richness.
3. The extent of the forest edge may be important for the number of bird species. Changes in plot size or shape to increase edge may maximise avian biodiversity, although the minimum area required for other types of fauna must be considered.
4. The type and extent of shrub layer influence the abundance of some species. Increasing the light penetration to encourage ground cover should increase both the diversity and density of birds.

At the end of the ongoing project, a more complete assessment will be made of the potential for such enhancement, drawing both on new Irish data and on research from other countries (Jardine, 1988; Avery and Leslie, 1990; Hunter, 1990; Peterken, 1993; Fuller, 1995).

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Peer reviewed paper
Irish Forestry **55(2)**

Deposition of ammonia to a Norway spruce (*Picea abies* (L.) Karst.) stand at Ballyhooly, Co. Cork

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Abstract
Emission of ammonia from manure spreading influences the nitrogen input and acidity of forest ecosystems in agricultural areas. This is mainly due to the interaction between ammonia in ambient air and the forest canopy. The foliage canopy effect can be considered as the difference between precipitation and throughfall fluxes, i.e. net throughfall, and is the result of leaching, dry deposition, uptake and emission. Net throughfall calculated after a heavy shower preceded by a relatively dry period results in total wash-off, which is equivalent to total deposition when no canopy exchange occurs.

Precipitation and forest throughfall fluxes in an agricultural area (Ballyhooly, Co. Cork) have been monitored since 1989. This provides information on dry deposition of ammonia in relation to throughfall composition. Net throughfall fluxes for ammonia at Ballyhooly show a strong seasonal effect. The flux is clearly greater during the summer, which is probably the result of increased dry deposition of ammonia due to manure spreading. Negative net throughfall fluxes during spring indicate an uptake effect. Throughfall fluxes for certain ions can be used as an estimate of total deposition. Due to canopy uptake, however, total deposition of ammonia at Ballyhooly is higher than the throughfall flux.

Keywords: ammonia, dry deposition, canopy uptake, critical loads, forest ecosystems

Introduction
The Forest Ecosystem Research Group (FERG) operates a series of intensive forest monitoring plots in Ireland, with the aim of quantifying the interaction of atmospheric deposition on forest ecosystems (Farrell *et al.*, 1993). In agricultural regions, ammonia from manure spreading may be a significant source of nitrogen (Isermann, 1991). At Ballyhooly, Co. Cork, Ireland, throughfall (precipitation collected beneath the forest canopy) and precipitation fluxes (flux or load is the ionic concentration multiplied by the water volume) have been measured since 1989. This provides information on the behaviour of atmospheric nitrogen in forest ecosystems. The research site is located in a stand of

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Norway spruce (*Picea abies* (L.) Karst.) planted in 1939 on an orthic podzol soil derived from sandstone colluvium (Boyle *et al.*, 1996).

Gaseous and particulate matter in the atmosphere are primarily removed by rainfall (wet deposition) or directly deposited onto terrestrial surfaces (dry deposition). Dry deposition to forests is much greater than to other terrestrial ecosystems, due to the so-called scavenging effect (Farrell *et al.*, 1993). Elevated ammonia concentrations in the air can usually be attributed to local emission sources, as ammonia is removed during long-range transport by dry deposition and solution in water droplets (Asman and Van Jaarsveld, 1992). This implies that nearly all the ammonia detected at Ballyhooly originates from within Ireland. Estimates of ammonia deposition for Ballyhooly are presented in this paper.

Influence of ammonia on throughfall pH

Ammonia (NH_3) has a considerable influence on throughfall chemistry. It neutralises acidity in precipitation and throughfall, forming ammonium (NH_4^+):

$$NH_3 + H^+ \rightarrow NH_4^+ \quad (1)$$

The pH of throughfall may be higher than that of precipitation following dry deposition of ammonia, due to the removal of hydrogen ions according to Equation 1. In the relatively unpolluted environment of Ballyhooly (Farrell *et al.*, 1993), the concentration of acid species is often low and the ionic content is largely neutral seasalts. Therefore, the concentration of ammonia determines the pH to a large extent. In Figure 1, it can be seen that high pH events in throughfall are associated with high ammonia concentrations. This neutralisation is, however, short-lived, as the added ammonium reaching the soil increases soil acidification, either through plant uptake of ammonium or through the microbial transformation of ammonium to nitrate (nitrification) (Reuss and Johnson, 1986).

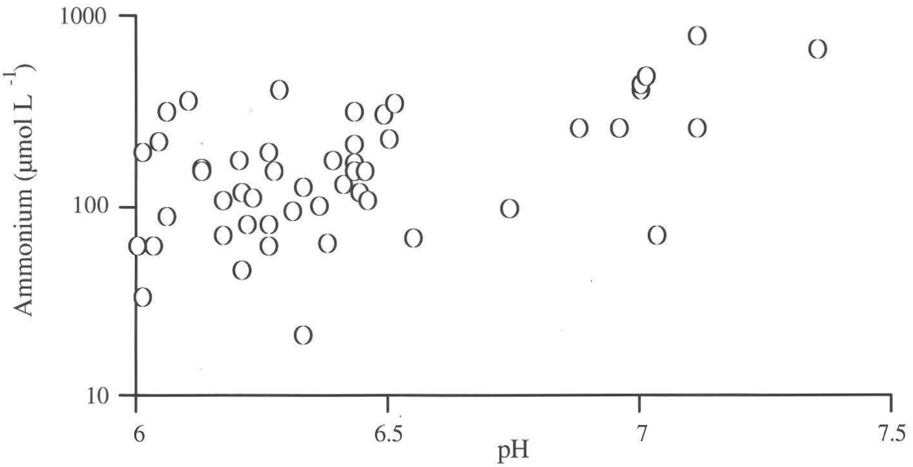

Figure 1. *Ammonium concentration against pH in throughfall at Ballyhooly, 1989-94. High pH events are associated with high concentrations of ammonia.*

Net throughfall of ammonium

Ammonium in throughfall is the result of four processes: (i) wet deposition of ammonia; (ii) dry deposition of ammonia; (iii) wet deposition of ammonium; and (iv) dry deposition of ammonium. The difference between throughfall and precipitation load - net throughfall - only reflects the input of dry deposition:

$$\text{Net throughfall} = \text{Throughfall} - \text{Precipitation} \quad (2)$$

It is assumed that ammonia is the main component of dry deposition, due to the observed high atmospheric concentrations (Van den Beuken, 1993). This explains the very high pH and throughfall concentrations of ammonium observed after long dry periods (Figure 1). Mean annual net throughfall of ammonium (230 mol/ha/yr) for Ballyhooly appears to be rather small, lower than the precipitation (310 mol/ha/yr), which is the result of NH_x uptake by the canopy foliage (Boyle *et al.*, 1996). On occasion, however, the net throughfall ammonium flux is high while the mean annual net throughfall flux is low.

Assuming no canopy exchange (direct uptake by canopy vegetation), total deposition is equivalent to net throughfall when all dry deposition is washed off, which only occurs after a heavy shower. Six years of monitoring data, 1989-94, have been divided subjectively into periods of 3 to 9 weeks. Periods were selected so that each ended with a heavy shower, which was assumed to represent total washoff. Net throughfall was estimated according to Equation 2. A plot of net throughfall flux for these periods (Figure 2) shows a strong seasonal effect. The negative net throughfall fluxes in early spring indicate net canopy uptake. This is surprising, as the emission of ammonia is expected to be high due to high ammonia volatilisation rates from slurry spreading during the warm weather of late spring/early summer (April-June). The uptake of ammonium through foliage appears to regulate the net throughfall. In autumn (September-October), when temperatures are still high but tree growth is concentrated in timber and buds rather than in nitrogen-rich foliage, the net throughfall load is greater. This may be the result of dry deposition of ammonia due to manure spreading which is not masked by canopy uptake.

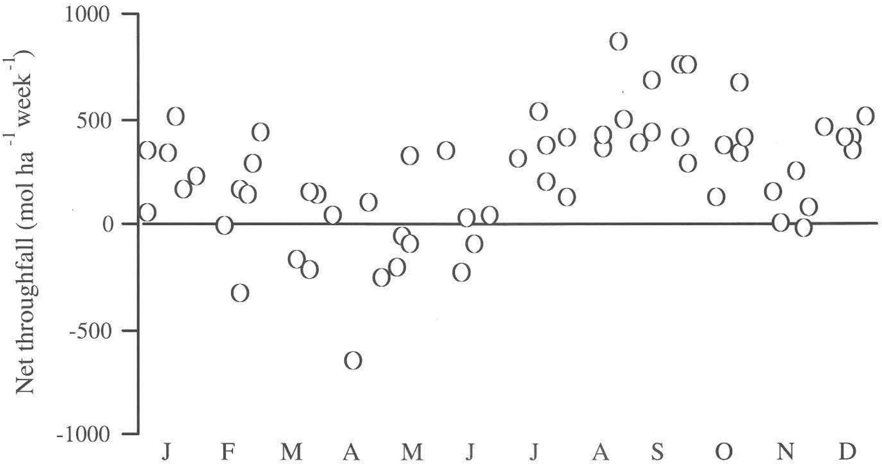

Figure 2. *Net throughfall fluxes for Ballyhooly. Each point on the graph represents mean weekly throughfall for periods of 3-9 weeks from 1989 through to 1994.*

Total deposition of NH_x

Throughfall flux is the result of processes which include both dry and wet deposition, but also absorption through foliage and canopy leaching. Canopy interactions must be taken into account when comparing throughfall and total deposition. Due to canopy uptake, throughfall is not a good estimate of total deposition (Figure 2). There are a number of methods which can be used to estimate total deposition of ammonium. Following the method employed by Draaijers and Erisman (1995), the canopy budget model has been applied to Ballyhooly to estimate total deposition of ammonia. The canopy budget model was developed by Ulrich (1983) and extended by Van der Maas and Pape (1991). The model discriminates between canopy exchange and atmospheric deposition using long-term throughfall and precipitation fluxes. Full details are given by Draaijers and Erisman (1995).

It is also possible to estimate dry deposition flux using inferential modelling which is based on air concentrations and deposition velocities:

$$F = V_d.c \quad (3)$$

where F is dry deposition flux, V_d is deposition velocity, and c is air concentration (Wesely, 1989). The relationship between air concentration and dry deposition flux, expressed in the deposition velocity, is however complicated by differences between chemical species and particle size, and is highly dependent on weather conditions. By assuming an appropriate deposition velocity, Van den Beuken (1993) observed that elevated ammonia concentration levels indicated significant dry deposition fluxes at Ballyhooly. Full details on the application of inferential modelling to Ballyhooly are given by Van den Beuken (1993). In Table 1, total deposition estimates for Ballyhooly, derived from the canopy budget model and inferential modelling, are presented along with measured throughfall for ammonia.

Table 1. *Estimates of total deposition of NH_x for Ballyhooly (total deposition = wet deposition + dry deposition).*

	Total deposition estimates mol/ha/yr
Throughfall	540
Canopy budget	978
Inference model	1,280

The estimated total deposition is quite tentative, due to uncertainties associated with the methods used. The canopy budget model is based on several assumptions which are not properly evaluated, and the total deposition derived from inferential modelling is highly dependent on the chosen deposition velocity. The inference model probably results in an over-estimation, as it is not based on a representative set of measured concentrations (Van den Beuken, 1993). Despite the uncertainties, both methods clearly show that throughfall cannot be considered as an estimation of total deposition due to the strong canopy interaction.

Critical loads of N

Based on the canopy budget model (Table 1), a conservative estimate for total deposition of NH_X is 1,000 mol/ha/yr, which is equivalent to 14 kg N/ha/yr. In recent years, pollutant loads of nutrient nitrogen have been described in terms of critical loads as "a quantitative estimate of an exposure to deposition of N as NH_X and/or NO_Y below which empirical detectable changes in ecosystem structure and function do not occur according to present knowledge" (UBA, 1996). Critical loads of nutrient nitrogen for acidic coniferous forests have been set at 10-50 kg N/ha/yr (UNECE, 1994). Taking only the deposition of NH_X into account (i.e. excluding NO_Y), it is clear that there is an exceedance of the critical load of nutrient nitrogen for Ballyhooly at the lower end of the range. The effects of an exceedance of critical load may not be obvious or seem harmful, as trees may grow faster due to the indirect fertilisation by ammonia deposition. Biodiversity may, however, also be affected.

Conclusion

Ammonia originating from agricultural activity has a great effect on the throughfall chemistry in Ballyhooly. Due to canopy interactions, throughfall chemistry is further influenced. Uptake through foliage controls the throughfall load to a large extent. Therefore, throughfall cannot be used as an estimate for total deposition, as it can greatly under-estimate the true value.

Dry deposition of ammonia from agricultural activities is the main input of anthropogenic pollutant species. The total deposition of NH_X is considerably higher than the throughfall load (approximately 45-55% greater). Based on the critical loads of nutrient nitrogen (10-50 kg N/ha/yr), the total deposition of NH_X suggests an exceedance at the lower end of the range for Ballyhooly.

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Peer reviewed paper
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Chemically modified wood – a review with consideration of the opportunities for application to Irish timber

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Abstract
Chemical modification offers the opportunity to improve the dimensional stability and biological durability of wood. In the modification process, reagents are introduced which react permanently with the structural polymers cellulose and lignin, reducing their hygroscopicity and attractiveness as a fungal food source. Acetylation, in which the wood is reacted with acetic anhydride, was one of the earliest approaches used, and remains the most promising technique, with at least one European project now at the pilot plant stage. Although the reactive materials and the process require careful handling, the treated material presents none of the toxicity hazards associated with wood preserved by conventional means. Acetylation may give sufficient property improvement to allow fast grown softwoods to be used in higher value joinery applications, thus increasing the scope for utilisation of native materials.

Keywords: Acetylation, chemical modification, durability, anti-shrink efficiency

Introduction
Chemical modification has long been seen as a way of improving the stability and durability of wood, but despite extensive investigation since the key publications on reaction with formaldehyde (Tarkow and Stamm, 1953) and on acetylation of wood in lumber thickness (Goldstein *et al.*, 1961), relatively little practical use has been made of the idea. Attempts at commercialisation in the USA in 1961 (Anon., 1961) and in the USSR in 1974 (Otlesnow and Nikitini, 1977) were discontinued, presumably for commercial rather than technical reasons. This situation may soon change, as a number of European centres have projects underway which are approaching industrial scale, and awareness of the potential advantages of chemical modification has increased. The purpose of this review is to consider the general principles involved, to examine some of the recent developments, and to comment on opportunities for application to Irish timber.

The improvement in properties associated with chemical modification is largely obtained through the control of the moisture uptake capacity of the wood. Dimensional instability in wood subject to varying environmental conditions is largely caused by the absorption or loss of moisture by the hydroxyl-rich structural polymers. The associated swelling or shrinkage is highly anisotropic, and the resulting mechanical stresses lead to checking and other forms of gross damage. A high concentration of available hydroxyl groups is also important for maintaining the minimum 20% moisture content needed for decay-causing fungi to thrive. If wood is treated in such a way as to reduce the hydroxyl concentration, or to permanently prevent the hydroxyls from binding with water, then a considerable improvement in physical and biological properties can be expected, and this is the basis of chemical modification. Figure 1 compares wetting isotherms for modified wood with a control, illustrating the point about moisture absorption.

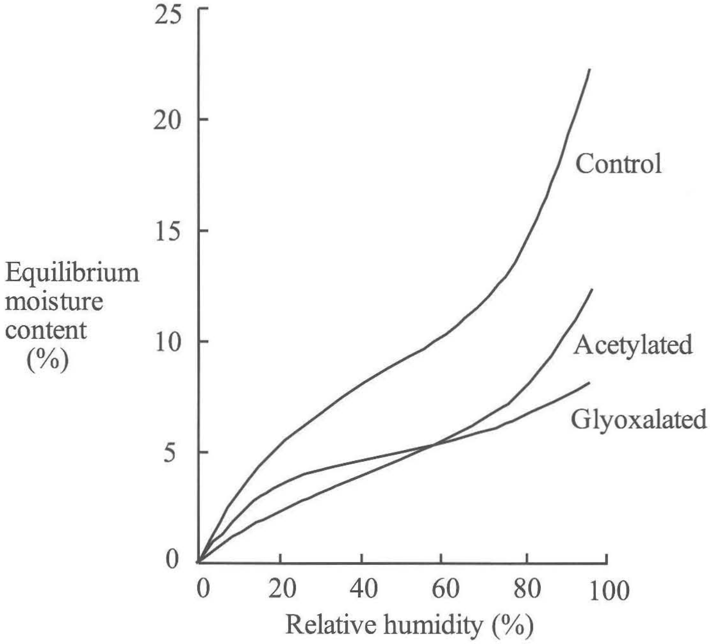

Figure 1. *Absorption isotherms for Sitka spruce (*Picea sitchensis *(Bong.) Carr.) modified with acetic anhydride (21.3 WPG) and with glyoxal (17.2 WPG). From Yasuda* et al. *(1995).*

Chemical modification also brings extra benefit in that the chemistry of decay depends upon the ability of fungally produced enzymes to 'recognise' the wood polymer repeat units as a food source, and then release them for metabolisation. Modification of the wood substrate can prevent the enzyme binding reactions (Peterson and Thomas, 1978) and the subsequent depolymerisation. Thus there are two rather different methods of protection at work in modified materials, one physical and the other chemical. The physical contribution is through improvement in hydrophobicity, while the chemical contribution is through substrate modification. Hydrophobicity can be altered by wax impregnation (Rowell and Banks, 1985; Banks and Voulgaridis, 1980), which tends to change the rate of approach to the equilibrium moisture content, but not the ultimate value. Chemical modification changes the kinetics of moisture absorption and wood swelling, and reduces the equilibrium moisture content at any particular humidity level. Figure 2 illustrates the difference between chemically modified wood and wood treated with a hydrophobic substance such as wax. The stabilisation of the moisture response explains why acetylated wood has been proposed (Yano *et al.*, 1993) for the manufacture of musical instruments.

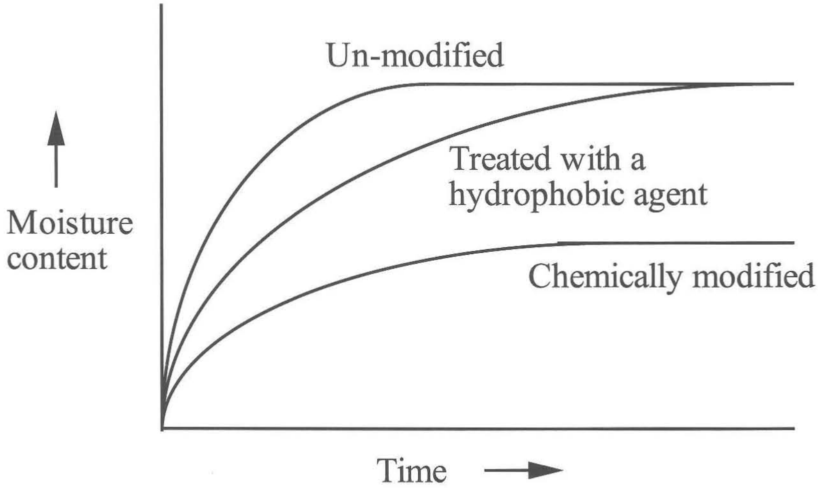

Figure 2. *Relative moisture uptake of chemically modified wood and wood treated with a hydrophobic agent such as wax.*

Most effective wood preservation methods present considerable environmental hazard, but this should not be the case with chemical modification. Although the reagents used are themselves toxic, if the process is carried out properly, reactions go to completion and the final products contain no harmful residues. Treated wood can be handled with complete safety, and waste wood disposal problems are greatly reduced.

Much experimental evidence is now available from many laboratories to support these general assumptions about durability improvement and environmental benefit, forcing the question about why the process has not been widely adopted. Problems are both technical and commercial. The technical problems of chemical modification are associated with the practicalities of conducting chemical reactions in a semi-solid cellular matrix, where physical factors of penetration and diffusion may dominate the chemistry. Although many of the reactions are simple in principle, the complex nature of wood makes it very difficult to work out important details about which molecular species are reacting and how it is happening. Penetration of reactants was always seen as a difficulty. The majority of the earlier publications dealt with modification of feedstocks for wood composites, such as flakeboards, with the feasibility of treatment of timber in joinery sizes hardly ever considered, despite Goldstein *et al.*'s (1961) landmark paper. Recently, reports of extensive practical trials (Beckers and Militz, 1994; Beckers *et al.*, 1994 & 1995) have shown that timber of practically useful dimensions can be treated by acetylation at the laboratory scale. The greatest challenge now lies in translating the process from the laboratory to the mill or factory. Scale-up is currently being attempted in the Netherlands, where approximately 40 companies have come together to form the acetylation company Acetyleer Kennis B.V. This initiative has been led by the independent Foundation for Timber Research at Wageningen.

Questions of economics are more complicated, as they are intertwined with environmental factors. Costs are going to be considerable, but if modified native timber can compete on the grounds of stability and durability with the highest grade Canadian or Scandinavian imports, then clearly the process has merit. Indications from Wageningen are that acetylated spruce (*Picea* spp.) claddings will work out at approximately 1,150 Guilders (approximately IR£520)/m^3, and pine (*Pinus* spp.) for joinery at 1,700-1,750 Guilders (approximately IR£770-800)/m^3. These can be compared with meranti (*Shorea* spp.), currently widely used in the Netherlands, at 1,800 Guilders (approximately IR£820)/m^3. When scale-up is achieved there, it will be easier to assess the likely cost structures which would apply in Ireland.

Measuring the benefits of modification

If wood is going to be subjected to the expense of modification, and if different modification techniques are to be compared, then it is important to be able to quantify the benefits obtained. Weight percent gain (WPG) is the most common term used to specify the degree of modification, and has obvious meaning. It is important, however, to remember that it does not distinguish between chemically and physically bound materials which may respond in different ways to continued extraction with water. Acetylated wood is typically treated to give approximately 16 WPG.

The mechanical and physical benefits of modification can be conveniently expressed in terms of two parameters. The anti-shrink efficiency (ASE) of the modification can be obtained (Rowell and Ellis, 1978) by comparing the swelling of the modified material with that of a control, as the materials are cycled between oven dry and equilibration at 98% RH:

$$ASE = ((S_c - S_m)/S_c) \times 100$$

where S is the volumetric swelling in percent, and is given by:

$$S = ((V_w - V_d)/V_d) \times 100$$

V_w and V_d are the wet and dry volumes, and S_c and S_m are the shrinkages.

Anti-shrink behaviour is often described by plotting dimensional change through a series of wetting and drying cycles. Figure 3 shows such a plot and compares modified wood with a control. A high ASE confers the obvious benefit of overall dimensional stability, and greatly reduces the problems posed by knots and grain defects. Paint adhesion is also consequently improved.

Anti-creep efficiency (ACE) can be measured by 3-point bending tests. It has been proposed (Norimoto *et al.*, 1992) that it should be expressed in the same way as ASE:

$$ACE = ((dJ_c - dJ_m)/dJ_c) \times 100$$

where dJ_c and dJ_m are the creep compliances of control and modified materials, and are given by:

$$dJ = (4wt^3 / F I^3) \times (f_0 - f_1)$$

F is the applied load, f_0 is the deflection before unloading, f_1 is the deflection after loading, I is the span, w is the width and t is the thickness.

ACE is of interest because of the central role of water and hydrogen bonding in mechano-sorptive creep. If modification interferes with hydrogen bond concentration and water interaction, then it can be expected to have an impact on creep properties. Norimoto *et al.* (1992) plotted ASE versus ACE to map property change for wood subject to a series of treatments. A simplified version of their plot is shown in Figure 4. The treatments which have a beneficial effect on both ASE and ACE can be clearly identified and compared.

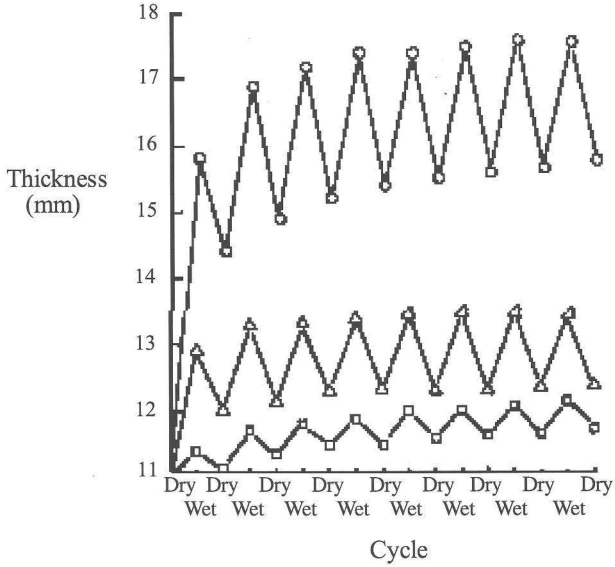

Figure 3. *Thickness of chemically modified flakeboard. Symbols: o control; Δ butylene oxide at 18.2 WPG; □ acetylated at 24.4 WPG. From Rowell* et al. *(1986a).*

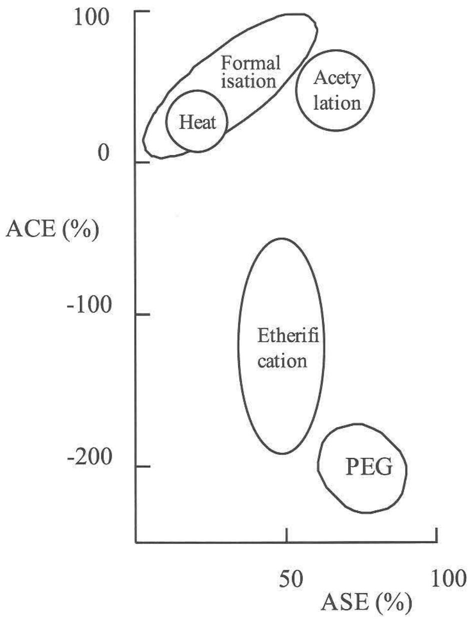

Figure 4. *Plot of anti-shrink efficiency versus anti-creep efficiency. Only materials with an ACE above zero are likely to be of value for structural applications. After Norimoto* et al. *(1992).*

Fungal durability improvement is more difficult to quantify, due to inherent biological variability and the range of test methods. There are, however, numerous publications detailing the fungal resistance of chemically modified wood under all kinds of test conditions. These include field trials (Beckers *et al.*, 1995), laboratory soil block tests (Chen, 1994) and fungal cellar observations (Nilsson *et al.*, 1988), in which parallel exposures of modified and unmodified materials have been followed by visual assessment, weight loss or strength loss measurement. All show impressive improvement in durability. In tests according to EN113 and EN 807, non-durable hardwood and softwood acetylated to a WPG of 15 reach durability class 1. This means that acetylated beech (*Fagus* spp.) will have a durability at least equal to iroko (*Chlorophora excelsa*), a timber which is still very popular for door and window joinery in Ireland. This opens up the possibility that a native species with high amenity value could be used to replace tropical hardwood.

Modification and bulking

Before looking at the chemical detail of modification processes, it is useful to clarify the relationship between modification and bulking. Bulking of wood with materials such as polyethylene glycol (PEG) is well known and is used in the preservation of cellulose based historical artefacts. It relies upon the hydroxyls of the glycol creating strong hydrogen bonds with the wood polymers and replacing water lost from the cell wall during drying (Stamm, 1964). In this way, shrinkage, distortion and cracking are minimised. Bulking agents such as PEG are very effective as dimensional stabilisers, but greatly increase the creep propensity of the wood (Norimoto *et al.*, 1992). This is probably because applied mechanical stresses exceed the activation energy barrier for hydrogen bond hopping, and the bulking agent effectively functions as a molecular level lubricant, facilitating chain rearrangement. Leaching is also a problem. Therefore, although important in the specialised field of archaeological conservation, hydrophilic bulking agents have little to offer to industrial timber technology.

Chemical modification with reactive materials such as anhydrides or epoxides, relies on the formation of primary chemical bonds between the reactant and the lignocellulosic materials, usually through reaction with the hydroxyls. The wood polymers are therefore chemically changed, and dimensional stability, creep resistance and biological durability are all improved, as previously described. All chemical modifiers will have an associated bulking effect, the magnitude of which will depend upon the size and type of chemical group which becomes attached. This means that a given molar addition of, for example, propionic anhydride, will bulk the cell wall more than the equivalent amount of acetic anhydride. Hill and Jones (1996) reacted wood with a homologous series of anhydrides, to give uniform percentage weight gain but different percent hydroxyl substitution. They found that dimensional stabilisation depended simply upon the WPG and not on the hydroxyl substitution, as might have been expected. From this, the authors concluded that dimensional stabilisation can be accounted for purely as a bulking phenomenon. This must mean that in wood modified with a higher molecular weight anhydride, free hydroxyls are present in the cell wall but are screened by the hydrocarbon tail of the modifier.

Figure 5 schematically illustrates the actions of various types of agent. The key point with the chemical modifier is that it is tied to the wood by primary chemical bonds, eliminates some hydroxyls and limits access to others. The modifier is not free to facilitate creep, which is why wood treated with anhydrides has better creep resistance than unmodified wood.

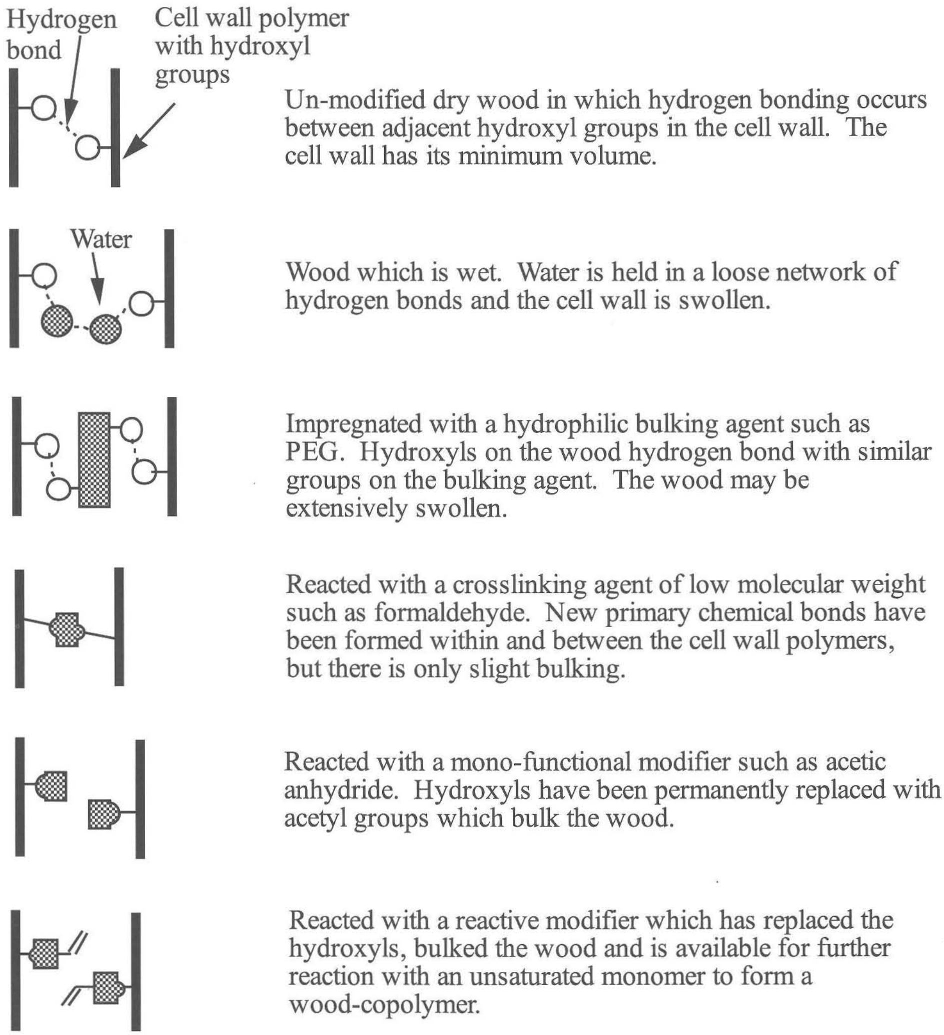

Figure 5. *Schematic illustration of the effects of different types of chemical agent on the cell wall.*

Both simple bulking and chemical modification result in a volume change which is broadly predictable (Rowell and Ellis, 1978) from consideration of the molar volumes of the species involved. The bulking effect is important, as it means that shrinkage on drying will be followed by expansion during modification. The wood is therefore stressed twice, with opportunity for manifestation of faults. Due to this, one of the goals of those trying to develop the process is direct modification of wet wood, so that the drying shrinkage is counterbalanced by the modifier bulking effect. If this can be achieved, then the problems of knots and grain irregularity will be minimised. With Irish softwoods, this clearly has to be a major consideration.

The chemistry of modification

Figure 6 details some of the important reactions used in chemical modification. The scheme is based on reaction with cellulose hydroxyls. Reactions with lignin are not given because, although in some cases they are important, it is still not clear what they are. As shown, much, but not all, modification chemistry depends upon the reaction of electrophiles with the cell wall hydroxyl groups. Anhydrides, which react fairly rapidly with hydroxyls to give an ester link, have received the greatest attention. Three are of particular importance; acetic, succinic and maleic. There are important differences in the way they react.

Acetic anhydride reacts with cellulose, replacing a hydroxyl and liberating acetic acid, which must then be removed as it damages the wood and is corrosive to fixings. The acetylation reaction is acid or base catalyzed. Many catalysts are mentioned in the literature, but most pose insuperable practical problems for commercial processes. Strong acids degrade the wood, while pyridine and dimethyl formamide, which have been used extensively in some of the small scale trials, present unacceptable problems of residual contamination. The general trend has therefore been to move towards un-catalyzed reactions, driven forward by heat alone. As already indicated, questions remain about the details of acetylation chemistry. Pizzi *et al.* (1994) have suggested that acylation of the lignin is an important process. It is not clear if this occurs directly or through the rearrangement of acetylated lignin groups, but the implication is that crosslinking of the matrix material may occur and that some linking of the cellulose to the lignin may be possible. Such reactions would explain the improved creep properties of acetylated wood.

Maximum practical acetyl substitution is achieved at about 25 WPG, and acetylation to about 20 WPG in wood such as poplar (*Populus* spp.) gives an ASE value of about 70%. Wood acetylated to 15 WPG or above is effectively resistant to fungal decay (Takahashi *et al.*, 1989; Peterson and Thomas, 1978), but is not fungi-toxic in the way that materials treated with copper-chromium-arsenic (CCA) are. In agar plate tests, the hyphal tips will grow up to the modified wood specimen, but are not able to penetrate the cell wall.

Of the three commonly used anhydrides, succinic is the most reactive, followed by acetic and then maleic. Maleic and succinic react with wood to replace hydroxyls with new and potentially reactive groups. They do not release a by-product such as acetic acid, which is obviously an advantage. The attached reactive groups may be exploitable as a site for copolymerisation of the cell wall polymers with an unsaturated monomer, and it has been suggested that if the process is used as part of fibreboard manufacture, then the wood-polymer composite may have sufficient thermoplasticity at the intermediate stage to allow the production of profiles by extrusion. Experiments with maleic anhydride and methyl methacrylate monomer (Banks *et al.*, 1995) have shown that some copolymerisation does occur.

Of the anhydride processes, acetylation, using either liquid or gas phase reaction, stands out as that closest to commercialisation (Beckers and Militz, 1994; Beckers *et al.*, 1994 & 1995), even though some details of the chemistry still remain to be resolved. The reaction is carried out by exposing the wood, using vacuum impregnation in a stainless steel reactor, to acetic anhydride, followed by heating to promote reaction. A typical cycle (Beckers *et al.*, 1995) comprises 1.5 hours at a vacuum of 0.04 MPa, followed by exposure to anhydride at a pressure of 8.0 MPa, after which the excess anhydride is drained off and the wood heated under vacuum at 120°C for 3 hours. Time of reaction appears to be more significant than temperature. It is important that acetic acid released during the

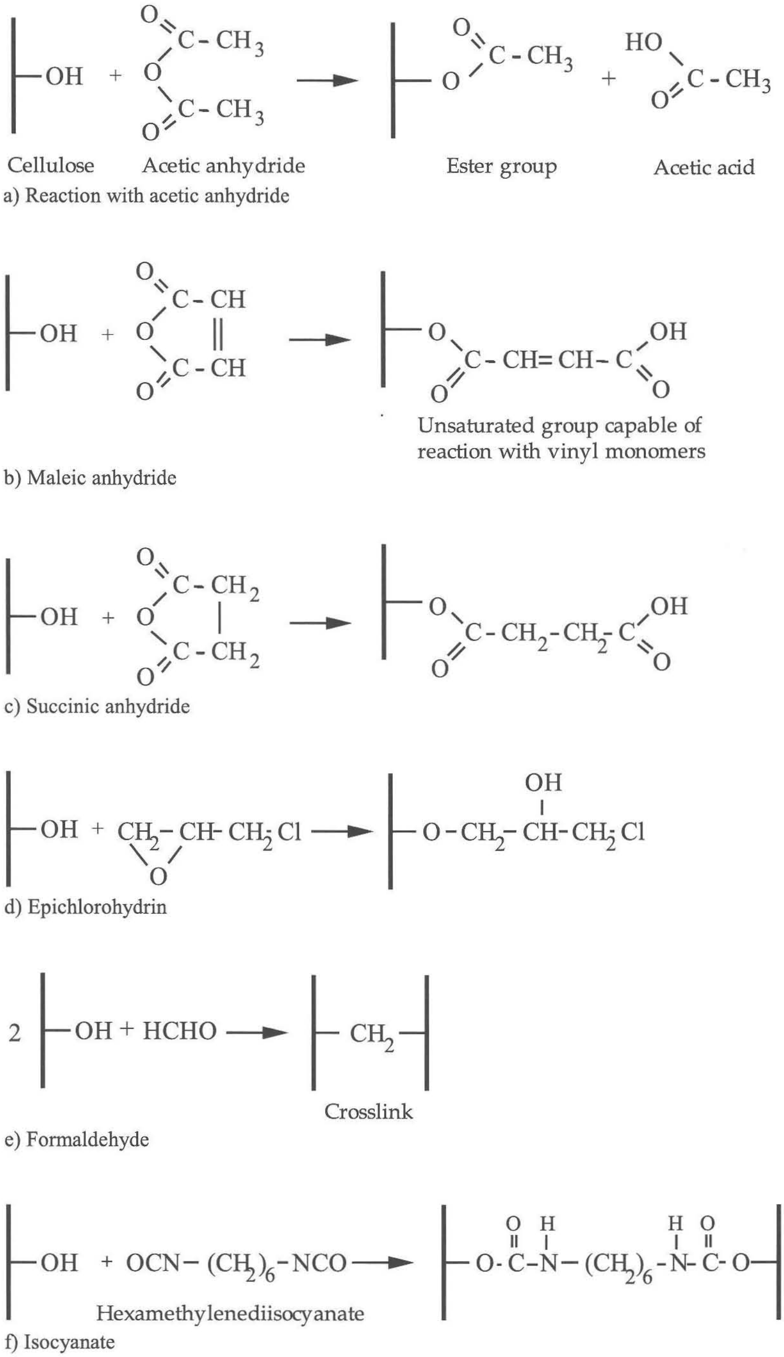

Figure 6. *Some of the chemical reactions used in modification.*

reaction is removed from the final product. The wood must also be relatively dry before treatment, as residual moisture competes for anhydride, wastefully reacting with it to liberate more acetic acid.

Wood morphology has a large effect on the efficiency of the acetylation process, but this is not simply a question of penetrability, as beech and poplar are both readily penetrated but show different rates of acetylation (Beckers *et al.*, 1995). Spruce is particularly difficult to acetylate, although acetic anhydride has been shown to achieve better penetration than normal aqueous preservative. It has been proposed (Militz and Homan, 1992) that this is because of degradation of the pectin in aspirated bordered pits by acetic acid. During acetylation, the wood swells almost to green state dimensions, and as reaction may preferentially occur closer to the surface in wood such as spruce, subsequent profiling may loose much of the benefit. This suggests that the process sequence should match the timber. In current work in the Netherlands, spruce cladding is profiled before treatment, while pine for structural applications is profiled after treatment. Profiling waste is completely harmless and can be disposed of or used along with other process waste.

Acetylation of the feedstocks for wood-based composites has also been extensively described (e.g. Rowell *et al.*, 1986a & 1986b; Clemons *et al.*, 1992), but again processes have not reached commercial realisation. The technical advantage of easy access of reactant to fibres or flakes makes the idea attractive, and Rowell's work shows that significant improvement in ASE can be obtained. This would lead to composites of improved mechanical integrity under wet conditions (Rowell *et al.*, 1988). Fitting the modification process into existing composite production lines would, however, not be easy, probably explaining why development emphasis has gone on binder research.

Beside the anhydrides, many other reagents have been investigated as possible wood modifiers. The more important of these are aldehydes, such as formaldehyde, isocyanates and epoxides. Formalisation, the reaction with formaldehyde, results in cross-linking within the cell wall, probably involving the lignin matrix, and because of this, there is a beneficial reduction in plasticity (Akitsu *et al.*, 1993) and creep (Norimoto *et al.*, 1992). Low levels of treatment provide a very high level of dimensional stability, with 7 WPG giving an ASE of 90% (Tarkow and Stamm, 1953). Unfortunately, the reaction is catalyzed by strong acids which cause wood degradation (Stevens *et al.*, 1979; Stevens and Parameswaran, 1981), with impact strength being particularly badly affected. There is also the additional health problem of free formaldehyde. The dialdehyde, glyoxal, presumably undergoes similar condensation reactions to formaldehyde, but has also been used in conjunction with glycol to form more complex condensation linkages.

Isocyanates have a high reactivity towards hydroxyls and react with the cell wall cellulose, without the use of catalysts, to form carbamate groups. Binders based on isocyanates are already in use in Ireland for the production of medium density fibreboard, and the reactions here are probably the same as those used in the modification of solid wood. Treatment with mono-isocyanates such as the n-butyl isocyanate leads to cell wall bulking and significant reduction in moisture absorption (Martin and Banks, 1991). Reaction of wood with a diisocyanates such as hexane diisocyanate or toluene diisocyanate may crosslink the cell wall material, as shown in Figure 6. Direct modification with isocyanates can be difficult because of premature reaction with moisture, and so acyl hydrazides have been proposed (Gerardin *et al.*, 1995) as the starting materials. Wood is impregnated with the pre-cursors and the *in-situ* release of the isocyanates, provoked by heating, limits the opportunity for premature reaction. The technique has, however, only been used with spruce meal and small 3 cm x 2 cm x 1.5 cm blocks, with pyridine as solvent. Weight gains were around 3.5% and 70% with block and meal respectively, when reacted with C_6H_5 CON_3. Chen (1994) has reported the use of chlorosulphonyl isocyanates reacted in pyridine, which acts as a solvent and catalyst, with blocks (1.9 cm) subject to rigorous drying. The wood was soaked in the reactant mixture for 24 hours and then reacted at 60°C for up to 24 hours to give a WPG of up to 14%. Some results are given in Table 1.

Table 1. *Effect of isocyanate and epichlorohydrin modification of loblolly pine (*Pinus taeda *L.) on resistance to decay by* Gloeophylum trabeum *in a 12-week soil block test. From Chen (1994).*

Treatment	*WPG*	*Weight loss by decay (%)*
Chlorosulphonyl isocyanate	2.56	14.9
	6.06	8.4
	14.69	0.6
Epichlorohydrin	2.15	37.4
	5.45	12.7
	10.86	2.3
Control		49.7

Epoxides will react with wood hydroxyls to give ether links, but there is good evidence (Norimoto *et al.*, 1992) that creep properties are poor. Some interesting observations (Chen, 1994) have been made with the epoxide epichlorohydrin, which, in the presence of triethylamine catalyst, reacts with wood to give a combination of alkoxy bonded side chains and wood-wood crosslinks. Table 1 compares the performance of isocyanate and epichlorohydrin modified wood, and illustrates what can be achieved in relation to fungal resistance. Creep resistance data does not seem to be available. Combinations of epichlorohydrin and glutaric anhydride have been reported (Goethals and Stevens, 1994) to give good ASE results. Sequential esterification and epoxidation, by elimination of the carboxyl group, should give a substituent with reduced hydrophilicity.

Another approach which has been considered (Rowell and Chen, 1994) is to use epichlorohydrin as a coupling agent to bind a bioactive compound such as pentachlorophenol to the wood. If the bioactive group contains a hydroxyl, it will condense with epichlorohydrin to give a glycidyl ether. This will still have an epoxy group and be able to further condense with the hydroxyls of the cell wall, binding on the bioactive group. In the same way, glycidylmethacrylate can be directly reacted with wood (Goethals and Stevens, 1994), and offers an unsaturated reaction site for subsequent copolymerisation.

Wood-polymer composites are a specialised area of modification. The target is usually copolymerisation of the lignocellulosic materials with a vinyl monomer such as methyl methacrylate (MMA). If this can be achieved, then substrate modification and hydrophobicity will be maximised, but the problems of diffusion of reactants are large and the process economics do not look promising. Maleic anhydride-methyl methacrylate combinations (Banks *et al.*, 1995) have already been mentioned. Lumen fill with MMA can be achieved and slightly reduces the rate of water swelling but does not reduce the extent of swelling (Feist *et al.*, 1991), implying that little cell wall penetration occurs. The MMA polymer acts as an additional matrix adhesive material and holds the cellulose fibres together during weathering, and as weathering is a surface phenomenon, it may be possible to simply surface treat the finished wood product. Many other wood polymer composites have been examined, including wood-phenol formaldehyde resins (Akitsu *et al.*, 1993) and wood-styrene systems (Stevens and Schalck, 1978).

Beside the few materials considered here, there are many other potential modifiers, and research into new systems continues. For example, the EU-supported Chemowood project, involving groups in Belgium, the UK, the Netherlands and Finland, is currently investigating a range of substances, including N-methylolacrylamide, furfuryl alcohol and various modified anhydride systems. These, and the other non-anhydride reactants previously mentioned, may in the long run prove useful, but their practical realisation does not appear to be imminent. Many of the reagents are expensive and somewhat difficult to handle, and scale-up work has not been attempted.

Conclusion

There is no doubt that a number of different chemical modification procedures are effective at improving the stability and durability of wood, but acetylation is the only process currently close to commercialisation. Within the next few years, significant amounts of acetylated timber may be in use in the Netherlands, and the technical and economic position of the process will become clearer. Timber utilisation patterns in Ireland differ from those in other European countries, but many of the same environmental and economic pressures apply. Before getting involved in modification, Irish mills and joinery manufacturers will require detailed cost information. Costs are going to be considerable, as the nature of the processes, involving corrosion-resistant pressure vessels, ovens and chemical handling, recovery and storage facilities, indicates a large investment compared with a CCA plant. It is therefore important to realise that acetylated timber is not simply a new method of preservation which will compete with use of CCA or borates, but is a way of upgrading the material to allow it to be used for higher value applications.

A significant cost benefit may arise through savings in waste wood disposal. European and national regulations are making handling, and in particular, disposal, of CCA treated materials problematic and potentially expensive. Acetylated wood can be dealt with and disposed of without any special precautions, and no environmental hazards are presented.

The investment required is within the capability of the large wood composite companies, but would be more of a challenge for the smaller units involved in solid wood processing. Economies of scale make it very difficult to envisage more than a very small number of modification plants in Ireland, but decisions about how these will be owned and operated rest with the industry and State bodies. The Netherlands example of the establishment of a joint company is one approach.

From a technical perspective, the way ahead is more straightforward. As the capability to acetylate timber becomes available on the Continent, sample quantities of Irish materials can be supplied for treatment. COFORD are currently funding a project at the University of Limerick to do this. In this project, mechanical and chemical properties of acetylated wood will be evaluated using standard tests, and biological durability investigated using accelerated procedures. Species being examined include Sitka spruce (*P. sitchensis* (Bong.) Carr.), lodgepole pine (*P. contorta* Dougl.) and Japanese larch (*Larix kaempferi* (Lamb.) Carr.). In the longer term, larger quantities of modified fast grown wood can be converted into products for field trials. Any problems of treatment penetration with fast grown spruce or pine would become clearer and could be addressed. Such a series of trials would be relatively cheap, and the information generated would allow a more informed decision about the adoption of the process and the economics involved.

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Effect of early formative shaping on newly planted broadleaves – Part 1: Quality

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Abstract
Formative shaping for quality was applied to 1,380 trees, commencing during the second growing season after planting. A similar number was kept as a control. The purpose of this trial was to assess the effect, if any, of formative shaping on early stem quality, height and diameter growth. Over a 4-year period, trees were assessed for quality annually after leaf-fall, using a standardised ranking system. This paper (Part 1) describes the effect of formative shaping on the quality of eight species included in the trial: common ash (*Fraxinus excelsior* L.); common beech (*Fagus sylvatica* L.); cherry (*Prunus avium* L.); pedunculate oak (*Quercus robur* L.); sweet chestnut (*Castanea sativa* Mill.); sessile oak (*Q. petraea* (Mattuschka) Lieblein); sycamore (*Acer pseudoplatanus* L.); and common walnut (*Juglans regia* L.). Overall, quality among trees of all eight species was improved by formative shaping. Part 2 describes the effect of formative shaping on height and diameter growth.

Keywords: broadleaves, leading shoot quality, formative shaping, quality measurement, apical training, early management

Introduction
It is estimated that between 20,000-25,000 ha of broadleaves will be planted in Ireland in the period 1990-99. Most of these plantations will be on moderately good to good quality farmland. Government policy indicates a broadleaf target of 20% of all new grant-aided planting (Anon., 1996). Including premium payments, this would suggest an investment in new broadleaf plantations by the European Union and the Irish Government of between IR£112-140 million. In this context, the development of management systems to promote quality in broadleaf plantations is a key element in achieving a return on this investment.

In commercial forestry, the most important part of any tree, particularly a broadleaf tree, is the lower section of the stem, as this is the portion which yields the greatest financial return. It is therefore essential that a sufficient number of quality stems from which to select the final crop are left *in situ* after first and second thinning. It is considered unwise to aim to have just enough quality stems at the second and third thinning stage to carry through to the final crop (approximately 500 stems/ha at year 20 for YC 12 common ash (*Fraxinus excelsior* L.) and sycamore (*Acer pseudoplatanus* L.), as indicated by Hamilton and Christie (1971)). Instead, it is essential to have in place during the early years a much greater number of quality stems than that required for an adequately stocked final crop.

The reason for advocating greater numbers is due to the high attrition rate of main stem quality in the early years following establishment (Balandier, 1997).

Lawson (1597, cited in Evelyn, 1664) provides one of the earliest references to formative shaping: "Neither let any man ever so much as think, that it is unprofitable, much less unpossible, to reform any Tree of what kind soever: for (believe me), I have tried it: I can bring any Tree (beginning betime) to any form." In a publication written in old English and entitled *Silva: or a Discourse of Forest Trees*, John Evelyn (1664) summarises what might be considered as best practice for today: "It is by the discreet leaving the Side-boughs in convenient places, sparing the smaller, and taking away the bigger, that you may advance a Tree to what determined Height you desire: Thus, bring up the Leader, and when you would have that spread and breakout, cut off all the Side-boughs, and especially at Midsummer, if you espy them breaking out. Young Trees may every Year be pruned and as they grow older at longer Intervals, as at three, five, seven or sooner, that the wounds may recover, and nothing being deformed."

From the forestry literature at the end of the 18th and beginning of the 19th century, there appears to have been two approaches to the planting of broadleaf species. One practice was to plant at wide, possibly final (7.6 m and over), spacing (Harris, 1998). This would be akin to current agroforestry methods, whereby each tree is intensively managed and tended. The second was to plant at high densities and to utilise the subsequent crowding effect to induce self-pruning. Main (1839) states that this latter practice "may be so far economical... but neither the soundness or the diametric bulk of the trees individually is promoted by such neglect. Superior trees will there be found, but they are only superior by accident." Nicol (1820) states: "Notwithstanding that we here fully admit the great utility of close masses for the procuring of straight clean timber, it must be obvious to everyone, that, for a number of the earlier years of the forest, however extensive it may be, the plants will not feel that influence from proximity which is necessary to give them the upright tendency or direction that is so highly desirable. Hence the necessity of early pruning of forest plantations."

There is little recent literature on formative shaping of broadleaves (Balandier, 1997). In a Forestry Commission handbook entitled *Urban Forestry Practice*, Hibberd (1989) describes formative pruning as "the removal of twigs and small branches", with "lopping" being the term applied to the removal of large branches. The same author indicates that formative pruning is best carried out to shape trees for the purpose of producing a desirable appearance and preventing the formation of weak forks. In an article on formative pruning, Kerr (1992) suggests that the objective of formative shaping "is to produce a single straight stem of at least 5 metres in length with small branches that will quickly die at the onset of canopy closure leaving the bole virtually defect free." In their publication *Growing Broadleaves for Timber*, Kerr and Evans (1993) suggest that formative pruning "is becoming increasingly important as a remedial treatment for the poorly developing form of many timber species planted in the last 10 years on bare ground." They indicate that "all species will benefit from some formative pruning but some more so than others." They identify oak and common beech (*Fagus sylvatica* L.), both lacking apical dominance, as two species most likely to require formative pruning. Bulfin (1992) suggests that the objective of formative shaping is "to stimulate the same effect on the crop as natural crowding in natural regeneration situations, which causes broadleaves to tend to grow straight and to lose their side branches at an early age."

A number of references refer to actual research work on formative shaping. In a publication devoted to formative shaping and pruning, Hubert and Courraud (1987) define the objective of formative shaping as "an attempt to give to the tree a satisfactory form and to obtain an optimum length of straight vertical stem." They define the process of formative shaping as "the suppression of double or multiple heads (leaders) or the slowing down or suppression of branches which, through too strong development, may risk damage to the trunk." Balandier (1997) states that it is necessary to distinguish systematic pruning, i.e. the pruning of a fixed length of stem to remove all branches (also referred to as stem pruning), from formative shaping. The concept of formative shaping in this research is based on that used by Hubert and Courraud (1987), which entails "suppressing the branches that interfere with the formation of a straight cylindrical bole." These authors define such branches as "forks, shoots with an acute angle of insertion, large branches competing with the main stem, etc."

In detailing his methods of apical training of blackwood (*Acacia melanoxylon*) in New Zealand, Barton (1993) states, in relation to failing leaders which form stunted growth, that "Stem remodelling requires occlusion of the pruning defect - a delay in pruning, or the retention of a stub, will delay occlusion and prevent remodelling." Where forking has occurred, the same author comments that "Forks are codominant stems, they lack a branch collar, and the defect after pruning is slow to occlude. Rapid occlusion and remodelling demand the early recognition of forks - delaying pruning until the following winter will leave a persistent stem kink."

Kerr and Evans (1993) state that their "guidelines are based on observation and some limited experience." In outlining the aim of formative shaping, they state that "the objective of formative pruning is to produce a single straight stem of at least 5 m in height with small branches that will die quickly at the onset of canopy closure leaving the bole virtually defect free." They advocate the removal of forks and disproportionally large branches, i.e. branches with "a diameter greater than 50% of the main stem at the point of intersection with the main stem." They further state that "ideally branches removed in formative shaping should not be allowed to become too large to cut with a knife or a secateurs." They also suggest that "the treatment should be started soon after establishment and ideally continued annually until the objective of a single straight stem of at least 5 m in height is satisfied." This echoes the words of Nicol (1820), who urges his readers "to commence pruning at the infancy of the trees and thence-forward to continue at intervals of one or at most two years."

Working with both broadleaves and conifers, Aufsess (1975) indicates that a protective zone develops at the base of branches even before the branch has died naturally. He suggests that the formation of the protective layer requires living parenchyma, and that in broadleaves, this protective layer cannot be complete where heartwood is present. This would indicate that formative shaping on young trees or pruning on older trees should be carried out before the onset of heartwood. This work indicates that branch or fork removal should be carried out before branches reach 3.0 cm in basal diameter, as supported by Soutrenon (1995). Winterfeld (1956) found that, in dominant beech, pruning wounds healed twice as fast as scars left by naturally shed branches. He also found that fungal infection, which was invariably present, ceased to progress once the scar had occluded. Nicol (1820) suggests that it is preferable over time not to allow any branch, even twigs, to die *in situ* on the bole, as "These frequently become *dead branches*; and if such were allowed to remain at all on the trees, they would infallibly produce blemishes calculated greatly to diminish the value of the timber: hence the impropriety of allowing any branch to die on the bole of a tree. Indeed all branches should be removed when they are *alive*." Roth (1948) indicates that the early removal of branches is preferable. In dealing with pruning wounds on oak, he found that wounds more than 3.75 cm in diameter may result in decay.

In detailing when to prune or shape, Kerr (1992) relies heavily on the work presented by Lonsdale (1991) at a seminar entitled 'Research for Practical Arboriculture' in York, April, 1990. It should be emphasised that Lonsdale's work was confined initially to the practice of stub pruning (Lonsdale, 1987), but during the above seminar, he also detailed measurements of ridge and flush cut pruning methods. Lonsdale's ridge method corresponds to the pruning methods advocated by Shigo (1989a & b). Lonsdale also worked on the pruning of branches with a diameter of 5.0-8.5 cm. This is, however, outside the range for formative shaping, where, as most of the work is carried out using secateurs or loppers, branches removed are rarely greater than 2.0 cm in diameter. In discussing pruning, Evans (1984) states that "it is rarely worthwhile pruning branches more than 5 cm in diameter or higher (up the stem) than 5-6 m." The same author states that "generally pruning up to 3 m should be done at or prior to first thinning", indicating that he is not referring, in this context, to the process of formative shaping.

In dealing with the time of pruning of large branches, i.e. branches with a diameter up to 5.0 cm, Evans (1984) states that "For rapid wound occlusion most species are best pruned in late winter or early spring, but there are exceptions. To minimise sap exudation birches, maples and sycamore should be pruned at any time except the spring, and walnut only when in full leaf in July or August. Cherry should only be pruned between June and August to minimise the risk from bacterial and silver leaf disease. In general, to help prevent entry of disease, pruning should not be done between mid-March and the end of May when a tree is flushing since its resistance to infection is believed to be at a minimum at that period."

In dealing with when to shape, Kerr and Evans (1993) state that the timing for pruning applies equally to "formative pruning". Barton (1993) favours early summer apical training. He adds that, if a branch is allowed to grow through to the end of the season and then removed, "The energy locked up in the discarded branch could have been made available to the main stem leader, with a resultant increase in height and vigour. There has been a sharing, rather than a concentration, of growth potential. The discarded branch is therefore a 'lost opportunity'." Nicol (1820) agrees with this sentiment of lost opportunity: "Is it not evident, that if these branches had been timeously checked, the greater part of the matter forming their solid contents, would have settled in the trunk itself...whereas if the superfluous or competing branches had been removed annually and before they attained a large size, the places from which they issued would be imperceptible, or at least not hurtful to the timber...timely pruning is, therefore, a matter of the utmost importance."

Balandier (1997) clearly indicates that formative shaping is to be carried out in June-July. Hubert and Courraud (1987) also indicate that the optimum time for formative shaping is from mid-June onwards, after the effect of spring frosts has become apparent, and can be carried out by pinching off the new green forked branch tips by hand. They state that shaping at a later date, when some lignification has taken place, should be carried out using a secateurs, with branches cut at their base.

Background to shaping experiments

As described by Bulfin (1995), 2.0 ha of broadleaves were planted at the Teagasc Kinsealy Research Centre as a broadleaf mixture experiment. After the first year, the rate of deterioration in tree quality, as assessed by a specially devised quality ranking system, was alarming. Surveys of other broadleaf plantations and experience with ash and sycamore at the Teagasc Johnstown Castle Research Centre, Co. Wexford, and with other broadleaf species at the Teagasc Grange and Kinsealy Research Centres, indicated a similar pattern of decline in the number of quality stems. It became obvious that some form of remedial action was essential. In a 13-year old plantation of ash planted at 2,500 stems/ha, Ningre *et al.* (1992) found that only 30% of the trees remained unforked. It was therefore decided to apply the practices advocated by Shigo (1989a) and Barton (1993), to attempt to maintain good stem form and apical dominance. While his work concentrated on older trees, it was a postulation of this experiment that Shigo's pruning methods would be equally valid for the type of formative shaping advocated by Barton (1993).

In the context of this study, early formative shaping is defined as work carried out to maintain a single, straight stemmed and apically dominant leading shoot on broadleaf trees. Formative shaping commenced when the trees were less than 1.0-1.6 m in height (depending on species and planting stock), and was repeated each year, where required, up to a height of 3.0 m or more. It involved the removal of: (i) forks; (ii) codominant shoots competing with the leader; and (iii) disproportionately large branches lower down the stem which were likely to damage the long-term straightness of the stem. While these authors would agree with the target of 5 m of single straight stem advocated by Kerr (1992), achieving this would require extra effort and tools other than those used in this study, i.e. secateurs and loppers.

Methodology

During the 1992/93 planting season, 2.0 ha of broadleaves were planted at the Teagasc Kinsealy Research Centre, north Dublin (National Grid reference 3215 2430). As described fully by Bulfin (1995), the plantation comprised a broadleaf mixture experiment including 10 species in six different mixtures, with three repetitions of each mixture. The soil is classified as a moderately well drained grey brown podzolic of high base status, mostly derived from Irish Sea drift. The site is a smooth, very gently sloping field under continuous arable use prior to the establishment of the experiment. It is classified as a moderately exposed to exposed site, with little shelter from surrounding trees or hedges. It differs little from many new broadleaf plantation sites in Ireland, with the exception of its distance from the sea. Due to the research centre's proximity to the east coast, the site is particularly exposed to cold east winds. The ground was ploughed and harrowed prior to planting. After planting, simazine was applied at a rate of 3.0 kg/ha. Further physical, soil and climatic details pertaining to the site are provided in Table 1.

Table 2 lists the species planted in the mixture experiment, together with the number of individual trees of each included in the subsequent shaping trial.

No attempt was made to influence the quality of the planting stock, which originated from a number of commercial nurseries. This ensured that the type of material used in the trial was similar to that being delivered in the field. As a result, there was considerable variation in initial quality.

A spacing of 1.5 m x 1.5 m was used for pedunculate oak (*Quercus robur* L.), sessile oak (*Q. petraea* (Mattuschka) Lieblein), red oak (*Q. rubra* L.) and beech, and for some of the ash and sycamore. The remaining ash and sycamore were planted at 2.0 m x 2.0 m spacing, as were all of the remaining species, except common walnut (*Juglans regia* L.) and cherry (*Prunus avium* L.), which were planted at 2.5 m x 2.5 m spacing. As the newly planted trees were small and sufficiently far apart at these spacings not to be influenced by

Table 1. *Physical, soil and climatic details of the experiment site at the Teagasc Kinsealy Research Centre, Dublin.*

Physical features	
Elevation	35 m OD
Topography	Flat to gently undulating
Slope	0-3°
Aspect	North to northeast
Distance from sea	1.6 km
Soil data	
Soil classification	Grey brown podzolic
Texture	Loam to clay loam
Structure	Moderate to weak aggregates
Drainage	Moderately well drained
Parent material	Calcareous glacial drift of Irish Sea origin, predominantly limestone with some shale
pH	Topsoil ranges from pH 7.0-8.0
Organic matter	7-10%
Climate	
Exposure	Moderately exposed to exposed
Annual rainfall	700 mm
Annual air temperature	9.5°C mean (13.0°C mean max., 6.0°C mean min.)
Annual mean duration of bright sunshine	4.05 hours
Average annual actual evapotranspiration	455 mm

Table 2. *Species planted in the mixture experiment, and the number of trees of each included in the shaping trial.*

Species	*No. of trees included in shaping trial*
Common ash (*Fraxinus excelsior* L.)	826
Common beech (*Fagus sylvatica* L.)	156
Cherry (*Prunus avium* L.)	144
Pedunculate oak (*Quercus robur* L.)	234
Red oak (*Q. rubra* L.)	180
Sweet chestnut (*Castanea sativa* Mill.)	120
Southern beech (*Nothofagus procera* (Poepp. and Endl.) Oerst.)	80
Sessile oak (*Q. petraea* (Mattuschka) Lieblein)	156
Sycamore (*Acer pseudoplatanus* L.)	736
Common walnut (*Juglans regia* L.)	128
Total	2,760

each other's growth, each tree was regarded as an independent entity, i.e. a single tree plot.

A ranking system with five separate categories was devised to assess stem quality. This system was based on whether or not a tree possessed a single, straight stem and an apically dominant and vigorous leading shoot. As the trees grew, straightness and the lack of disproportionately large side branches on the developing stems were also taken into account. The objective of the quality ranking system was to assess whether each individual tree was capable of producing a stem of high quality timber.

The various categories are described below, with a visual guide to the characteristics of each given in Figure 1.

- Category 1: Very good quality, with straight stem and dominant leader.
- Category 2: Good quality, stem not as straight *and/or* tendency towards codominant shoots.
- Category 3: Moderate quality, stem somewhat wavy *and/or* shaped leaders not regaining straightness, still capable of improving with treatment.
- Category 4: Poor quality, stem forked, kinked or very wavy *and/or* prone to multiple shoots.
- Category 5: Very poor quality, bush-like, no observable apically dominant shoot.

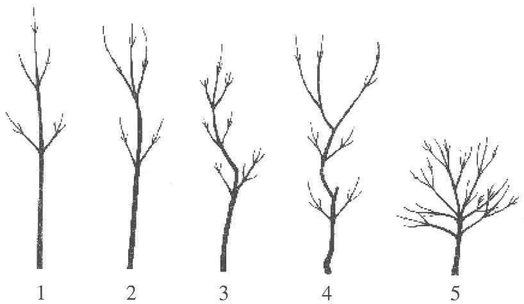

Figure 1. *A visual guide to the characteristics of Categories 1 to 5.*

Good vegetation control, using glyphosate, was applied in order to reduce variability in the experiment caused by weed competition.

Quality assessment was carried out each year after leaf-fall. Each species was judged on its own merits. Inter-species comparisons were not made and no statistical analysis between species was undertaken.

During the June/July period of the second growing season (1994), formative shaping was applied to trees in one half of each row, with trees in the second half remaining unshaped as an experimental control. In the case of forking, formative shaping involved the removal of the weaker or poorer quality shoot. Where competing codominants were present, all were removed or, where this might involve the removal of too great a portion of the foliage, the upper one third of each competing shoot was removed (a technique referred to as tipping). In some cases, a combination of the two treatments was used, with very strong codominants removed and others tipped. Finally, disproportionately large side branches (defined as branches with a basal diameter greater than 50% of the stem diameter at the point of attachment) lower down the stem were also removed. In this context, the relative size of the branch in relation to the tree, and not its absolute size, is the important factor. Only those trees requiring treatment were shaped. Each tree was assessed annually, receiving treatment only if necessary. Therefore, some stems in Category 1 in the shaped treatment may never have received a shaping treatment. Thus, the shaping treatment is related to the requirements of each individual tree, and the data relate to the aggregate of all trees in the shaped or unshaped treatments. Using each tree as a single plot, an analysis of variance was carried out between treatments for each species, to test for effect on quality.

Results

Red oak and southern beech (*Nothofagus procera* (Poepp. and Endl.) Oerst.) are both excluded from the following results, due to a general failure of both species on the site.

Loss of quality of unshaped trees

The performance of those trees which did not undergo shaping is of interest, as their progress indicates the rate of quality decline in crops receiving no formative shaping. During the first growing season (1993), the trend in most species was a dramatic overall decline in stem quality. Figure 2 details the percentage of trees of each species in Categories 1 and 2 combined, immediately after planting and at leaf-fall in the first year of the trial.

The greatest decline in quality during the first year took place in pedunculate and sessile oak, followed by sweet chestnut (*Castanea sativa* Mill.), walnut and sycamore. The decline in sycamore, which started out with over 85% of stems in Categories 1 and 2 combined, was serious, with only 40% remaining in these categories by leaf-fall of the first year. Ash and cherry showed the least decline in quality. The number of good quality ash stems immediately after planting was below 50%, but this level was maintained through the first year. Overall, however, these results indicate an obvious and serious pattern in the loss of quality in untreated plantation broadleaf trees during the first year of establishment.

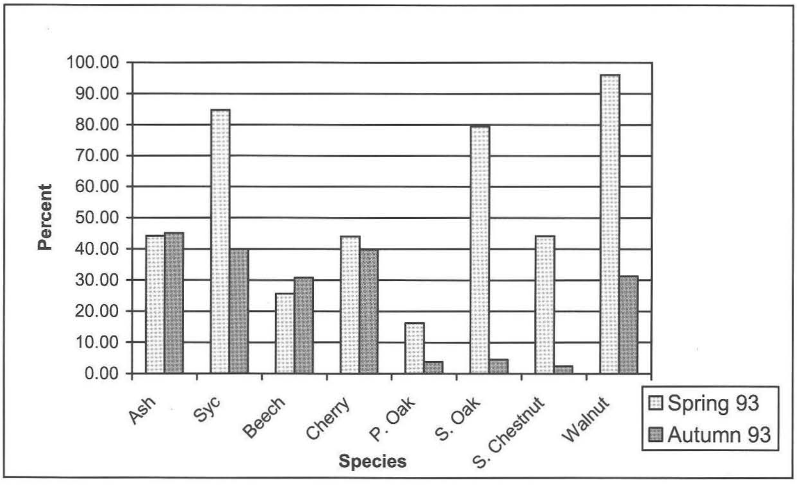

Figure 2. *Percentage of trees of each species in Categories 1 and 2 combined, immediately after planting (spring 1993) and at leaf-fall in the first year of the trial (autumn/winter 1993).*

Effect of formative shaping on quality

Figure 3 illustrates the percentage of all species combined within each of the five quality categories at the end of the fourth growing season (1996), demonstrating the general effect of shaping over the 4-year period of the trial. Within the shaped group, approximately 57% of those trees which underwent shaping were in the 'very good' or 'good' quality categories (Categories 1 and 2). Approximately 67% of the unshaped trees fell within the 'poor' or 'very poor' categories (Categories 4 and 5). When Category 3 trees are included, approximately 85% of the shaped trees lie within Categories 1-3.

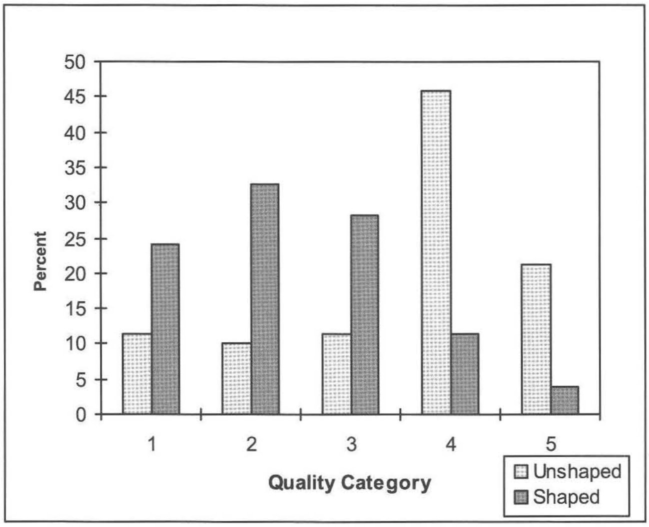

Figure 3. *Percentage of all species combined within each of the five quality categories at the end of the fourth growing season (1996).*

While Figure 3 indicates a general trend, there was considerable variation between individual species. This variation is detailed in Table 3, which lists the effect of formative shaping on the progress of each species. This is shown by giving the percentage of the total number of trees of each species in Categories 1 and 2 combined over the 1994-96 period. Table 3 shows that some species benefited more than others from early formative shaping. Although there was a slight improvement in quality within the unshaped group during the second growing season, the percentage of quality trees again decreased during the third season, followed by an even more dramatic decline during the fourth. Some species, notably sycamore and ash, declined in quality in the unshaped control, while maintaining or improving in quality in the shaped treatment. The percentage of Category 1 and 2 trees in the unshaped ash declined from 61.2% to 40.0% during the 1994-96 period, while that in the unshaped sycamore declined from 37.2% to just 8.2%. The percentage of Category 1 and 2 trees in the shaped ash fluctuated slightly each year, but was at least 25 percentage points better than that in the unshaped ash. The improvement in sycamore was also significant, with a continuous improvement recorded in the shaped trees. The difference between shaped and unshaped sycamore is the greatest for any species. Table 3 also indicates that the quality of some species within the unshaped group, notably sessile oak, gradually improved during this trial, due to the emergence of long straight shoots in the third or fourth growing season.

Table 3. *Percentage of the total number of trees of each species in Categories 1 and 2 combined over the period 1994-96.*

Species	*1994*		*1995*		*1996*	
	Shaped %	*Unshaped* %	*Shaped* %	*Unshaped* %	*Shaped* %	*Unshaped* %
Common ash	71.5	61.2	73.7	56.3	67.1	40.0
Common beech	41.9	47.2	54.7	63.9	74.4	50.0
Cherry	29.4	28.6	53.7	24.3	51.4	22.2
Pedunculate oak	19.7	7.4	21.9	7.4	30.3	10.3
Sweet chestnut	23.7	0.0	39.0	5.3	53.3	5.0
Sessile oak	21.4	6.3	21.4	10.6	28.6	16.7
Sycamore	46.3	37.2	53.7	29.6	62.2	8.2
Common walnut	3.1	0.0	31.3	21.9	39.1	10.9

Quality ranking of individual species

Table 4 lists the mean quality category of shaped and unshaped trees of each species, together with the level of statistical significance. It can be seen that formative shaping had a highly significant effect on the mean quality ranking of the different species. The effect on all species, except beech and sessile oak, was significant at the 0.1% level. Beech was significant at the 5% level. This clearly indicates the positive effect of formative shaping on the quality of the most commonly used broadleaf species planted at 1.5 m x 1.5 m to 2.5 m x 2.5 m spacing. Only one species – sessile oak – showed no statistically significant effect from shaping. The performance of oak in Kinsealy experimental plots was, however, generally poor over the period of the study.

Table 4. *Analysis of the mean quality category of shaped and unshaped trees of each species after four growing seasons (1993-96) (NS not significant; * significant at 5% level; ** significant at 1% level; *** significant at 0.1% level).*

Species	*Shaped*	*Unshaped*	*Significance*
Common ash	2.05	2.89	***
Common beech	2.02	2.61	*
Cherry	2.40	3.49	***
Pedunculate oak	3.23	3.96	***
Sweet chestnut	2.46	4.17	***
Sessile oak	3.26	3.67	NS
Sycamore	2.27	4.08	***
Common walnut	2.73	3.84	***

Additional analysis was carried out on the performance of trees of each species which were ranked in the two top quality categories. These trees represent the individuals most likely to be favoured during second and third thinning to form the basis for the final crop. Table 5 details the percentage of trees within the shaped and unshaped treatment within Categories 1 and 2 combined at the end of the fourth growing season (1996). The greatest percentage difference between shaped and unshaped is that for sycamore (54.0%), indicating that, of all those species studied, sycamore has benefited the most from formative shaping. Sweet chestnut and cherry also benefited from shaping, as indicated by a difference of 48.3% and 29.2% respectively. Beech, ash and walnut also show considerable differences, ranging from 24.4% to 28.2%.

Table 5. *Percentage of shaped and unshaped trees within each species in Categories 1 and 2 combined after four growing seasons (1993-96).*

Species	*Shaped* %	*Unshaped* %	*Difference* %
Common ash	67.1	40.0	27.1
Common beech	74.4	50.0	24.4
Cherry	51.4	22.2	29.2
Pedunculate oak	30.3	10.3	20.0
Sweet chestnut	53.3	5.0	48.3
Sessile oak	28.6	16.7	11.9
Sycamore	62.2	8.2	54.0
Common walnut	39.1	10.9	28.2

Figure 4 illustrates the performance of shaped and unshaped trees over the four growing seasons, 1993-96. Following a serious decline in quality during the first growing season, formative shaping improved the quality of most species over the following three seasons.

The quality of the original ash stock was generally poor, with only 44% falling into Categories 1 and 2 combined immediately after planting. There was little decline in the percentage of good quality ash over the first growing season (Figure 4a). This was followed by a slight improvement in stem quality over the next growing season. There was a slight decline in the third and a considerably steeper decline in the fourth growing season. While the rate of deterioration in stem quality in ash was not as rapid as that in sycamore, there was a serious rate of decline in the number of quality stems over the 4-year period of the trial. As forking and, to an increasing degree, windsnap, are the damaging defects in ash, the use of early shaping is essential in the production of a quality crop. When shaping is applied, ash maintains a substantial percentage of trees in the top two quality categories.

Sycamore showed the most positive response to formative shaping. There was a clear response to shaping in each year, while the unshaped trees showed a severe decline in quality (Figure 4b).

The quality of the original beech planting material was poor, with just over 20% of the trees falling into Categories 1 and 2. Considerable filling-in was required during the second and third year after planting. The quality of the filling-in material was better, and this, allied with the onset of side shelter, increased the number of individuals in the top categories. In the third (1995) and fourth (1996) growing seasons, beech performed well. In these latter years, the response of the species to shaping was very encouraging (Figure 4c).

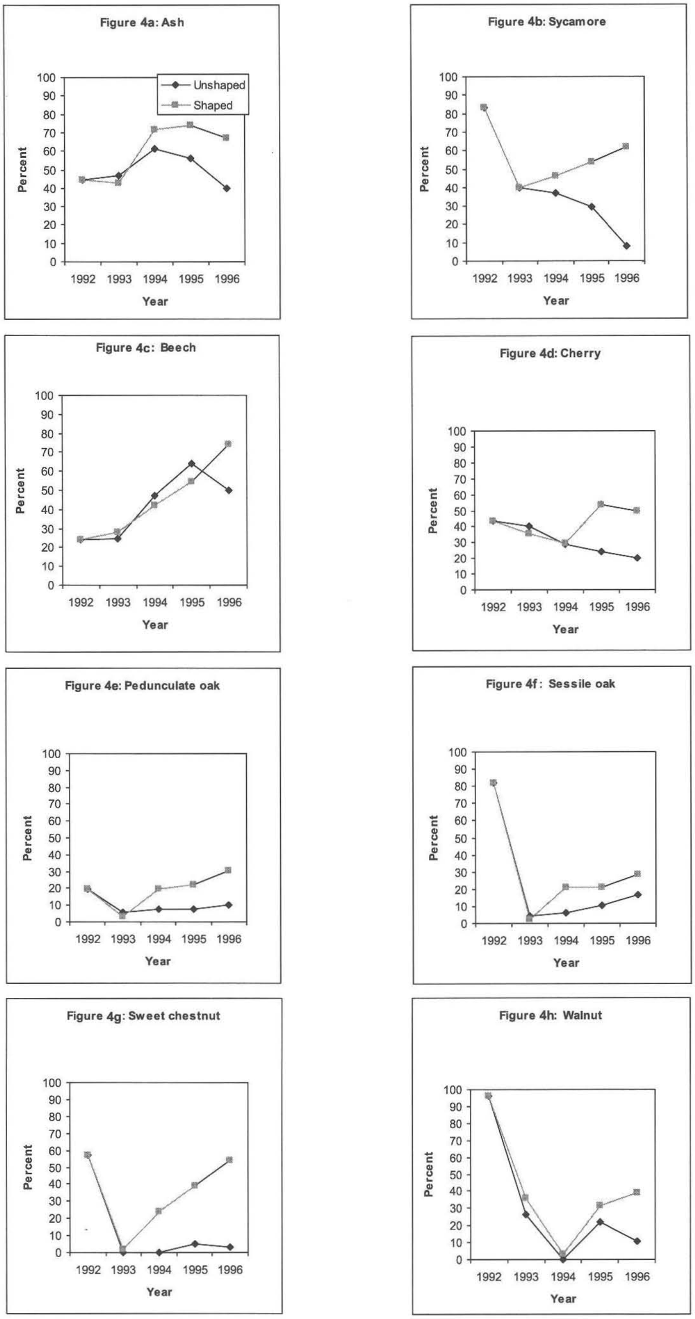

Figure 4. *Percentage of trees of each species in Categories 1 and 2 combined in the shaped and unshaped treatments, 1992-96 (Note: 1992 represents the planting season winter 1992/spring 1993).*

From 1994, the effect of shaping became more evident. In 1996, the percentage of good quality trees in the unshaped treatment declined, while the percentage of good quality trees in the shaped treatment continued to increase.

Cherry tends to be a very coarse branching species. While the unshaped cherry resembled orchard trees at the end of the fourth season, the gap between the shaped and unshaped treatments declined in the later years (Figure 4d).

While the initial quality of sessile oak was quite good, both pedunculate and sessile oak suffered severe decline in quality after the first season's growth. Formative shaping had some positive effects, as shown by the increase in the gap between shaped and unshaped trees (Figures 4e and 4f).

The quality of sweet chestnut declined seriously during the first growing season (Figure 4g), possibly due to exposure. The number of stems within the top quality category fell from 41% to just 3%. While unshaped trees remained at this low level throughout the duration of the trial, shaped trees greatly improved over the years. The number of individuals within Categories 1 and 2 increased to 54%, but the overall quality is still not good.

Formative shaping had a slight positive effect on walnut in the first two growing seasons. This effect increased in the final two seasons (Figure 4h).

Discussion

This experiment was originally designed as a broadleaf mixture trial. Due to the alarming rate of decline in the quality of the newly planted trees, a formative shaping trial was subsequently incorporated. The lower stem section is the portion of the tree which yields the highest financial return, either as sawlog or veneer. It is therefore essential that a sufficient number of straight quality stems from which to select the final crop remain after first and second thinning. It is also essential, particularly from the perspective of the private owner, that the material extracted in early thinnings is of sufficient quality to provide a valuable interim income. The British Forestry Commission recommends that 500 stems should remain *in situ* after the third thinning at year 20 for yield class 12 ash and sycamore, with a top height of approximately 15.0 m (Hamilton and Christie, 1971). The basis of a valuable crop will have been laid down if, at this stage, there is at least 6.0 m of straight, unforked and branch-free stem on most of the candidate trees. This indicates a need to have in excess of this number of quality trees available before first and through second thinning.

During this trial, it was decided to apply the pruning practices advocated by Shigo (1989a & b) and Barton (1993), in an attempt to maintain good stem form and apical dominance. The basic purpose of the experiment was to test the application of these broadleaf pruning methods to very young trees. The primary objective of the formative shaping was to maintain as many single, straight and apically-dominant leader shoots in the crop as possible. This was done by concentrating on apical training and the removal of disproportionately large side branches. Normal side branches which contributed to the welfare of the tree and which did not threaten stem form, were retained.

Effect of formative shaping on quality

The rapid decline in leading shoot quality recorded in this trial gives considerable cause for alarm. The rate of this decline is of crucial importance for the long-term availability of sufficient quality stems from which to select a final crop. Decline in the first year may be due to shock following lifting and replanting. Some species, most notably oak and beech, are more prone to planting shock, but there was also a serious decline in quality of sweet chestnut. While the quality of pedunculate oak was initially poor, even the better quality stems declined further. The decline in quality of sessile oak was even more dramatic.

Decline in stem quality of healthy trees after the first year in this trial reflects climatic factors, disease or inherent defects. The continuation of this decline in subsequent years raises serious concern regarding the quality of unmanaged broadleaf plantations. The annual fluctuation in the rate of loss of quality may be attributed to yearly variation in climatic or other factors. Formative shaping is essential to maintain a sufficient number of quality trees from which to select, where the attrition rate in early years of main stem/leading shoot quality is high (Balandier, 1997). Low forks in the first and second year, and multiple forking at the start of each year, were common problems among the unshaped trees included in this trial. Heavy side branches competing with weakened leading shoots, was also a common fault found among the unshaped groups of both oak species.

Formative shaping with secateurs and loppers up to 3.0 m in height contributed significantly to the quality of the lower stem of a number of broadleaf species studied, with sycamore, ash, beech and sweet chestnut benefiting the most. It is believed that formative shaping of all species will minimise core defects, enabling valuable girth increase. With the changes in veneer processing technology, such reduced defect cores will allow smaller diameters to be processed, thereby contributing to the value of the crop.

The timing of formative shaping should be based on the developmental stage of the tree, with height growth and leader development being the main criteria. Formative shaping should begin when the trees are between 1.2-1.6 m in height. Particular attention is needed over the first four years (particularly on fertile sites where vigorous growth takes place), during which period stem height is likely to reach between 2.0-4.0 m. Decisions should be based on the rate of decline over the first four years in the number of Categories 1 and 2 trees. Unless there is a sufficient number of shaped stems in place by the time the trees reach 3.0 m, straight, unforked quality stems cannot be created or induced later in the rotation. The formative shaped trees can be expected to be among those remaining after first and second thinning, and from which the final crop trees will be selected.

Forked stems or stems with multiple shoots at 1.0-3.0 m above ground level cannot be brought up to a sufficient quality by stem pruning in later years. Once these defects have become lignified, removal of one half of a fork will not result in the remaining leading shoot straightening into a good stem. A distinct bend occurs at the pruning site, referred to as a "bayonet" by Balandier (1997). Stems that have heavy lignified branches at 1.0-2.0 m above ground, and allowed to grow for a number of years, will also remain deformed after late pruning. The earlier shaping takes place, the better chance the tree has of straightening or "remodelling", as Barton (1993) describes it.

In the case of forking, it should be noted that both shoots constitute stem from a physiological perspective. Any form of shaping should therefore be carried out as early as possible after fork formation. Early June is considered best, as the shoot is still green and lignification has yet to take place. Hubert and Courraud (1987) advise the early "pinching off" (by hand, if necessary) of the green shoots of a fork. These authors indicate mid-June as the optimum time for this operation.

In the unshaped treatment, some species showed an improvement in form in the later growing seasons. Such improvement is, however, not guaranteed, nor does it occur in a sufficiently large proportion of stems to justify a non-intervention policy in the early management of broadleaf plantations. Thus, if quality broadleaves is the objective, there is a clear argument for formative shaping. Unless there is a sufficient number of quality stems at this stage of the crop, they cannot be created later during the rotation.

The performance of individual species to formative shaping

Comments on the response of individual species to formative shaping are given below.

Ash: Ash responded well to formative shaping in this trial, and due to its fast vigorous growth, is a prime candidate for early shaping. Only 44% of the ash was ranked in the top two quality categories immediately after planting, indicating low initial quality. The rate of fall-off in quality among unshaped ash was a serious problem, with forking and windsnap in trees greater than 2.0 m in height becoming major problems. While the rate of decline of trees initially classified as good was not rapid, it seemed to accelerate in the final two years. The experience of this study was that stems ranked as Category 3 because of forking or codominant leaders, could be brought into Categories 1 or 2 by judicious shaping, due to the 'plastic' and responsive nature of young shoots. The earlier one side of a forked stem is removed, the sooner the remaining shoot tends to straighten and move towards the vertical.

Sycamore: Of all those species studied, sycamore benefited the most from formative shaping, responding well to the removal of forks or codominants. The effect of formative shaping is particularly important, as the rate of fall-off in quality among the unshaped trees was dramatic, with just 8.2% remaining in the top two quality categories after four years. The main problem observed was the loss of the leading shoot bud, which led to the development of several competing codominant shoots. As with ash, however, the results of this study suggest that stems ranked as 'moderate' because of forking or codominant leaders, could be brought into Categories 1 or 2 by judicious shaping. In both sycamore and ash, due to the rapid growth of long straight leading shoots, formative shaping will result in significant lengths of good quality stem growth, adding substantially to the potential value of the crop.

Beech: Beech planting stock delivered at the beginning of this trial was small and of very poor quality, with significant filling-in required after the first year. Replacement stock was of better quality and once established, grew well. Results for beech are therefore confined to those trees which survived and grew into the 1996 planting season. Although slow to establish, the species is now one of the most impressive performers on this difficult site. Beech does not tolerate exposure and has a particular requirement for side shelter. In the latter years of this trial, beech was sheltered by the taller ash and sycamore, with which it was mixed. This suggests a possible establishment technique for beech on difficult exposed sites. It may be more profitable to plant beech in mixtures, and even to delay the planting for several years, while 'shelter wells' are created by surrounding trees of other included species.

Pedunculate and sessile oak: Both species of oak were of very poor form after the first growing season, with many trees developing a multiplicity of tiny twiggy branches. The development of profuse light branching made it difficult to detect any dominant leader which could be favoured during shaping. During the third and fourth growing season, however, a number of trees of both species produced long leading shoots. While some of these may be induced with shaping, most were crooked or at too steep an angle from the vertical to form good stems. Shaping did, however, make a small difference, raising the number of quality stems from 12% to 19% for sessile oak, and from 9% to 21% for pedunculate oak. While the effect of shaping on pedunculate oak was shown to be significant, practical observations suggested that no conclusions can be made from this trial regarding the formative shaping of oak at this stage of crop development. In general, unless the crop is performing exceptionally well, it is difficult to recommend shaping for oak until it produces a recognisable leading shoot, which, depending on the vigour of the plantation, tends to appear between year 3-5. Once the young trees begin to produce distinct long

shoots, shaping in favour of these shoots may prove effective. Another alternative is 'stumping back', a treatment whereby poorly shaped and bushy plants are cut back to ground level and allowed to form straight coppice shoots, which are then singled to produce a suitable quality leader. This leader may subsequently require formative shaping.
Cherry: Cherry suffered from canker (*Pseudomonas* spp.) during the trial, so all comments must be taken in this context. Formative shaping did not appear to have added to the level of canker. The cherry tended to grow rapidly and achieved the greatest average height and stem diameter of all of those species studied. Even with formative shaping, it was difficult to control the quality of cherry and to confine growth to a single stem. As cherry is regarded as a valuable timber, formative shaping may still be relevant, as any increase in the length of good quality lower stem has the potential to add considerable value. Unshaped cherry tended to fork and to produce a multitude of heavy branches, resulting in an orchard-type form, with branching occurring at 1.0 m or less above ground level and a relatively thick stem close to the base. The application of formative shaping in an attempt to curb this growth pattern involved considerable branch removal, resulting in a tree with a somewhat spindly appearance. Although cherry benefited, the prevalence of canker makes shaping a questionable exercise. Unless provenance studies or disease-free selection procedures are developed for cherry, the canker problem calls into question the future of cherry as a forestry species in Ireland.
Sweet chestnut and walnut: Sweet chestnut and walnut were affected by frost and exposure during this trial, and were generally not suited to the site. The form of both species in the unshaped treatment was distinctly globular and bush-like in nature. Within the shaped treatment, however, some stems were held to good single leading shoots of acceptable quality. The straightening response, which was clearly evident among the shaped ash and sycamore, was not so apparent in sweet chestnut and walnut, resulting in the retention of kinks in the stem over the period of the trial. Results do, however, indicate that formative shaping can contribute to improved quality in sweet chestnut planted on suitable sites. Shaping produced some quality stems among walnut, but most of these were somewhat irregular. Overall, walnut produced very few quality stems, particularly when compared to ash and sycamore. As previously outlined, however, each species was assessed on its own merits.

Conclusion

In summary, the objective of early formative shaping is to produce an adequate number of quality stems to allow sufficient choice in the selection of final crop trees. Formative shaping greatly improved the lower stem quality up to a height of 3.0-4.0 m of many of the broadleaf species included in this experiment. Two of the most important species in the current national broadleaf planting programme, ash and sycamore, responded best to formative shaping. Thus, the overall conclusion of this experiment is that early formative shaping is a valuable tool in the management of broadleaf plantations under typical Irish conditions. The effect of formative shaping on height and diameter growth is described in Part 2.

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Effect of early formative shaping on newly planted broadleaves – Part 2: Height and diameter growth

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Abstract
Formative shaping for quality was applied to 1,380 trees, commencing during the second growing season after planting. A similar number was kept as a control. The purpose of this trial was to assess the effect, if any, of formative shaping on early stem quality. Over a 4-year period, height and diameter growth were also monitored, to assess the effect, if any, of formative shaping on these parameters. This paper (Part 2) describes the effect of formative shaping on the height and diameter growth of eight species included in the trial: common ash (*Fraxinus excelsior* L.); common beech (*Fagus sylvatica* L.); cherry (*Prunus avium* L.); pedunculate oak (*Quercus robur* L.); sweet chestnut (*Castanea sativa* Mill.); sessile oak (*Q. petraea* (Mattuschka) Lieblein); sycamore (*Acer pseudoplatanus* L.); and common walnut (*Juglans regia* L.). Formative shaping had a significant positive effect on the height growth of ash, sweet chestnut and sycamore, and a significant negative effect on the diameter growth of ash, cherry, sweet chestnut, sycamore and walnut. The negative effect on diameter is regarded from a silvicultural perspective as being of negligible importance. Formative shaping should commence as early as possible in the rotation, ideally when trees are 1.0-1.6 m in height.

Keywords: broadleaves, leading shoot quality, formative shaping, height growth, diameter growth, apical training, early management

Introduction
This paper is the second part of a study of formative shaping in broadleaves. Part 1 (Bulfin and Radford, 1998) describes the effect of formative shaping on the early stem quality of eight broadleaf species: common ash (*Fraxinus excelsior* L.); common beech (*Fagus sylvatica* L.); cherry (*Prunus avium* L.); pedunculate oak (*Quercus robur* L.); sweet chestnut (*Castanea sativa* Mill.); sessile oak (*Q. petraea* (Mattuschka) Lieblein); sycamore (*Acer pseudoplatanus* L.); and common walnut (*Juglans regia* L.). This paper (Part 2) reports on the effect of formative shaping on the height and diameter growth of these species. As stated in Part 1, "In the context of this study, early formative shaping is defined as work carried out to maintain a single, straight stemmed and apically dominant leading shoot on broadleaf trees…It involved the removal of: (i) forks; (ii) codominant shoots competing with the leader; and (iii) disproportionately large branches lower down the stem which were likely to damage the long-term straightness of the stem." Formative shaping was nor-

mally carried to at least 3.0 m above ground level. As suggested by Bulfin (1992), the objective of formative shaping is "to stimulate the same effect on the crop as natural crowding in natural regeneration situations, which causes broadleaves to tend to grow straight and to lose their side branches at an early age."

As described in Part 1 and recommended by Barton (1993), Balandier (1997) and Hubert and Courraud (1987), formative shaping in this study was applied in the June/July period, commencing during the second growing season and repeated annually, where required. There were a number of reasons for selecting this time of the year for shaping. At the end of winter, damage from frost and cold winds will result in dead leading shoot buds and dead or damaged leading shoots. In some cases, leading shoots which continued to grow late into the autumn may have been damaged by frost and subsequently attacked in their weakened state by disease. This damage weakens the leader, allowing it to be overtaken by branches lower down the stem which then become competing codominants. Also, in the case of ash, damage to the leading shoot bud in late spring may be caused by the ash bud moth (*Prays fraxinella*). It is only by early summer that all of these types of damage will have manifested themselves as a weakened or dying leading shoot or a dead terminal bud which has been replaced by two side buds to create a fork. In effect, shaping in the June/July period tackles the problem as soon as it becomes apparent, and before lignification has occurred. The new shoots are green and pliable and will tend towards the vertical. Remphrey and Davidson (1992), who worked extensively with ash, observed this plasticity in the case of natural shoot tip abortion, noting "a reduction in the angle of divergence of lateral shoots in response...the terminal replacements being the most acute." Two competing shoots in a fork still, however, tend to push each other apart, particularly at the base. The removal of one side of such a fork allows the remaining leading shoot to straighten and to assume as near vertical a position as possible. This shaping will limit the bayoneting defect caused by forking (Balandier, 1997).

Another major argument for summer shaping is to concentrate the vigour of growth onto one single leading shoot. Where shaping is delayed until late in the season, branches carrying up to half of the leaf area may be lost if one side of a developed fork is removed. Similarly, as described by Barton (1993), if a branch is allowed to grow through to the end of the year and then removed over the winter, "The energy locked up in the discarded branch could have been made available to the main stem leader, with a resultant increase in height and vigour. There has been a sharing, rather than a concentration, of growth potential. The discarded branch is therefore a 'lost opportunity'." Hubert and Courraud (1987) indicate that the optimum time for formative shaping is from mid-June onwards, after the effect of spring frosts has become apparent, and can be carried out by pinching off the new green forked branch tips by hand. This comment about hand shaping reflects the early stage at which shaping is recommended, to minimise the leaf area removed and to concentrate growth as early as possible on one single leader. Davidson and Remphrey (1994) indicate that there is differential compensation for such a loss of leading shoot, and that a replacement leading shoot from just below the dead leader is favoured over other shoots slightly lower in the crown. The early removal of one side of this incipient fork caused by leader death will concentrate this preferential energy into one replacement shoot.

Side branches contribute to the overall welfare of the tree stem below the point of attachment with the stem (Kozlowski and Pallardy, 1997; Shigo, 1989a & b). In species characterised by branches arranged in whorls (such as cherry), there is a distinct step in diameter above and below the whorl. One particular problem associated with pruning cherry is whether to remove all or part of a whorl. Total whorl removal may limit diameter growth, while partial removal will result in the development of large branches among those retained (Balandier, 1997).

The removal of living tissue in shaping may be construed as removing the growth potential of a tree. The question at issue is whether this removal has beneficial or detrimental effects on tree growth and quality. As described in Part 1 (Bulfin and Radford, 1998), formative shaping was found to have a generally positive effect on early stem quality of the eight broadleaf species studied. This paper reports on the effect of formative shaping on the height and diameter growth.

Methodology

This paper describes the effect of formative shaping on the height and diameter growth of eight broadleaf species. The background, site description and overall methodology for this experiment is described in Part 1 (Bulfin and Radford, 1998), with further details in Bulfin (1995). Height (measured to the highest living point on the tree) and stem diameter (measured at 20 cm above ground level) were recorded each year after leaf-fall. Formative shaping commenced during the second growing season after planting when trees were less than 1.0-1.6 m in height (depending on species and planting stock), and was repeated each year, where required, up to a height of 3.0 m or more. This is the height of a person standing on the ground and working with hand tools such as secateurs or loppers. Using each tree as a single plot, an analysis of variance was carried out between treatments for each species, to test for effect on height and diameter growth.

Results

Effect of formative shaping on height growth

Very distinct effects on height growth were observed among different species in response to formative shaping. As formative shaping is aimed at maintaining a single dominant leader, it is perhaps not surprising that the shaping treatment would have a positive effect on height growth. Increases in height growth after four growing seasons (1993-96) in response to shaping proved significant at the 0.1% level among ash, sweet chestnut and sycamore (Table 1). In the case of ash and sycamore, the control of damage through formative shaping appeared to have encouraged the development of straight leaders. These leaders subsequently grew longer than those of the unshaped trees, where growth and energy were dissipated over a number of competing shoots. With the exception of sessile oak and walnut, which showed a 2.3 cm and 1.2 cm decrease in height growth respectively, formative shaping appeared to have improved height growth of all species after four growing seasons (Table 1).

Height growth of trees in the ‘very good’ and ‘good’ quality categories (Categories 1 and 2; see Part 1) combined after four growing seasons (1993-96) is detailed in Table 2 and illustrated in Figure 1.

In Table 2 and Figure 1, the best trees from each treatment, which are most likely to be kept during first and second thinning, are compared. With the exception of cherry and walnut, there is a positive difference in overall height growth in favour of the shaped trees. Sweet chestnut showed the greatest difference in height growth (28.0 cm). Yet the average height of sweet chestnut for all categories was generally small at the end of the final growing season (129.0 cm and 103.5 cm for the shaped and unshaped trees, respectively). Within the shaped treatment, however, the average height of sweet chestnut trees in Cate-

Table 1. *Effect of formative shaping on height growth after four growing seasons (1993-96) (NS not significant; * significant at 5% level; ** significant at 1% level; *** significant at 0.1% level).*

Species	*Shaped* cm	*Unshaped* cm	*Significance*
Common ash	289.1	277.7	***
Common beech	122.6	109.9	NS
Cherry	300.2	295.7	NS
Pedunculate oak	103.1	101.1	NS
Sweet chestnut	129.0	103.5	***
Sessile oak	108.1	110.4	NS
Sycamore	235.0	215.2	***
Common walnut	138.1	139.3	NS

Table 2. *Height growth of trees in Categories 1 and 2 combined after four growing seasons (1993-96).*

Species	*Shaped* cm	*Unshaped* cm	*Difference* cm	*Difference* %
Common ash	290.0	275.4	14.6	5.3
Common beech	122.7	107.9	14.8	13.7
Cherry	300.9	304.8	-3.9	-1.3
Pedunculate oak	127.2	122.3	4.9	4.0
Sweet chestnut	134.3	106.3	28.0	26.3
Sessile oak	126.6	107.0	19.6	18.3
Sycamore	232.8	226.6	6.2	2.7
Common walnut	143.3	143.5	-0.2	-0.1

gory 1 ('very good') is 140.0 cm. This suggests that shaping has a beneficial effect on the height of sweet chestnut by concentrating growth into a single leading shoot. Sessile oak showed the second greatest difference in height growth (19.6 cm), but the general performance of oak was disappointing. Beech showed the third greatest difference (14.8 cm).

At 134.3 cm, height growth among Category 1 and 2 shaped sweet chestnut is well behind that of cherry, ash, sycamore and even walnut. As shown in Figure 1, there were no trees in Categories 1 and 2 among unshaped sweet chestnut and walnut for certain years. Cherry had the greatest height growth at 300.9 cm, followed by ash and sycamore. Ash and sycamore responded well to formative shaping (Table 2). Both showed a slight positive response in height growth to formative shaping, with respective improvements of 5.3% and 2.7% in shaped over unshaped trees.

The key point demonstrated by Figure 1 for all species, with the exception of pedunculate and sessile oak, is that the effect of formative shaping on differences in height growth is slow but cumulative over the four growing seasons. Both oak species showed an anomalous growth pattern, particularly at the end of the 1995 growing season.

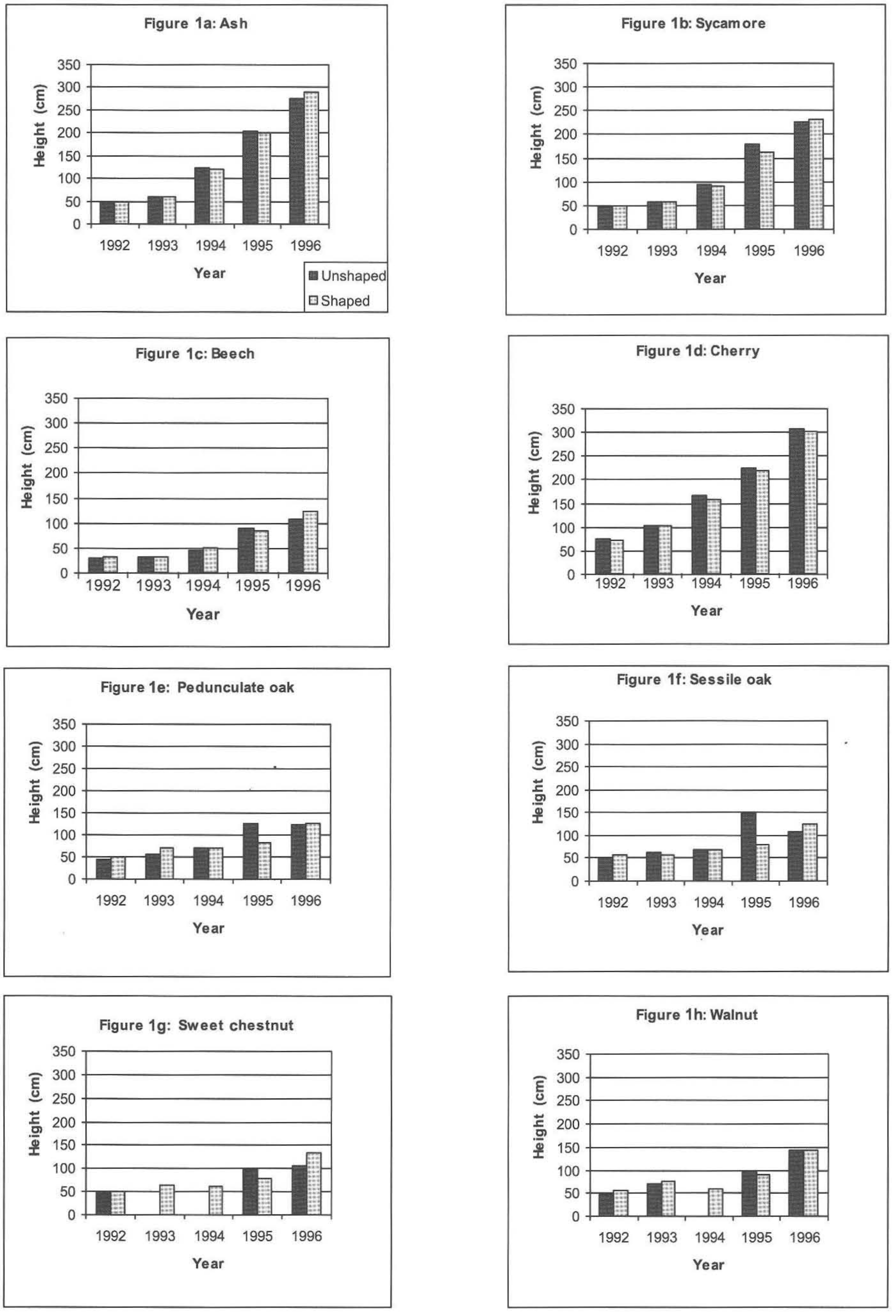

Figure 1. *The effect of formative shaping on the height growth of Categories 1 and 2 trees combined of eight broadleaf species, 1993-96. (Note: 1992 represents the planting season winter 1992/spring 1993).*

Effect of formative shaping on diameter growth

Table 3 details the diameter growth of all trees in all quality categories (Categories 1-5) after four growing seasons (1993-96). Formative shaping had a small but significant (at the 0.1% level) negative effect after four years of growth on the diameter of ash, cherry, sycamore and walnut. The effect was significant at the 5% level for sweet chestnut.

Table 3. *Effect of shaping on diameter growth after four growing seasons (1993-96) (NS not significant; * significant at 5% level; ** significant at 1% level; *** significant at 0.1% level).*

Species	*Shaped* *mm*	*Unshaped* *mm*	*Significance*
Common ash	42.0	46.3	***
Common beech	17.3	17.9	NS
Cherry	52.3	63.0	***
Pedunculate oak	17.4	19.3	NS
Sweet chestnut	32.3	36.0	*
Sessile oak	18.0	19.5	NS
Sycamore	35.7	39.9	***
Common walnut	38.5	47.1	***

The effect of formative shaping on diameter growth in relation to Categories 1 and 2 trees combined is detailed in Table 4 and illustrated in Figure 2.

Table 4. *Diameter growth of trees in Categories 1 and 2 combined after four growing seasons (1993-96).*

Species	*Shaped* *mm*	*Unshaped* *mm*	*Difference* *mm*	*Difference* *%*
Common ash	45.4	46.0	-0.6	-1.3
Common beech	18.0	17.7	0.3	1.7
Cherry	60.6	63.8	-3.2	-5.0
Pedunculate oak	19.5	25.4	-5.9	-23.2
Sweet chestnut	35.2	41.0	-5.8	-14.1
Sessile oak	20.3	28.7	-8.4	-29.3
Sycamore	39.7	38.9	0.8	2.1
Common walnut	46.5	47.2	-0.7	-1.5

The progress of diameter growth over the four growing seasons, as shown in Figure 2, indicates that, with the exception of pedunculate and sessile oak, diameter growth is similar for shaped and unshaped. In the case of pedunculate and sessile oak, diameter growth begins to diverge in the final two growing seasons.

When analysis is confined to Categories 1 and 2, the results differ from the overall statistical analysis of all quality rankings. The greatest physical differences in diameter now occur in the two oak species, with diameter growth in unshaped pedunculate and sessile

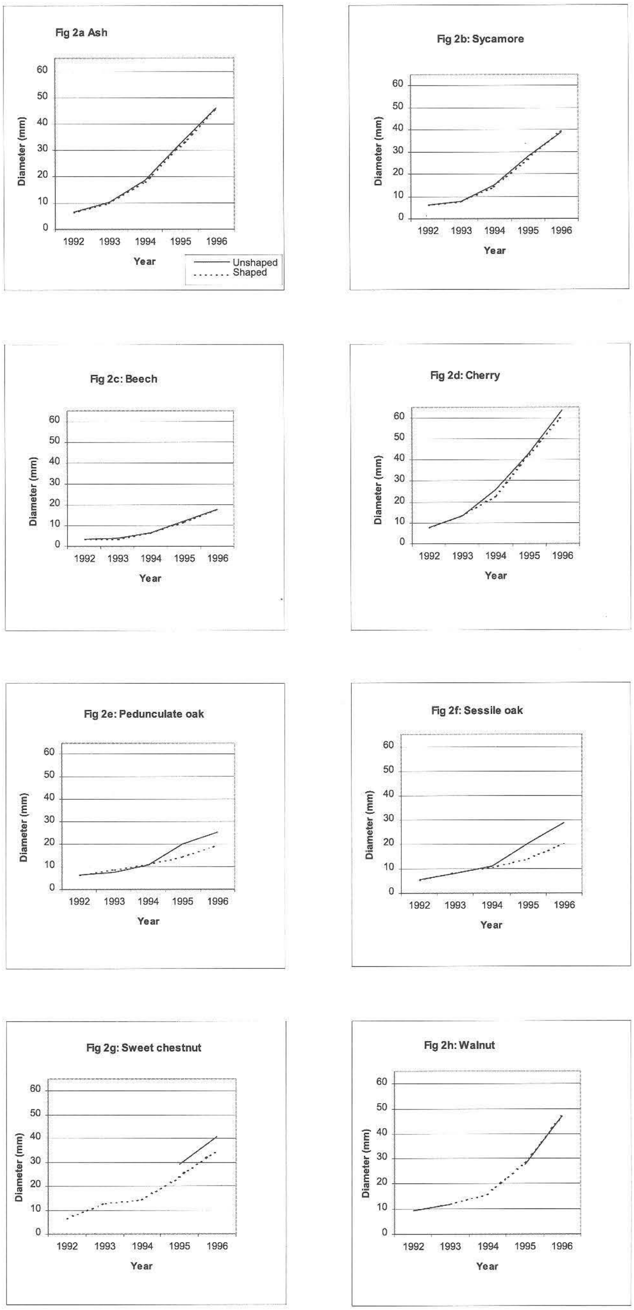

Figure 2. *The effect of formative shaping on the diameter growth of Categories 1 and 2 trees combined of eight broadleaf species, 1993-96. (Note: 1992 represents the planting season winter 1992/spring 1993).*

oak stems being considerably greater than that of their counterparts within the shaped group. This is to be expected, as any attempt to reduce oak to a single stem resulted in a considerable loss of branches and leaf area and an associated loss in diameter increment. In the case of sweet chestnut, attempts to develop a single dominant shoot by shaping resulted in a considerable loss of branches and leaf area, and a concomitant loss of 14.1% in diameter growth. It is noted that losses in diameter growth were greatest among species displaying the bushiest and poorest form in their unshaped state, i.e. sessile oak, pedunculate oak and sweet chestnut. The loss in diameter growth within pedunculate and sessile oak appears greater due to the poor overall growth of these species over the 4-year period. Ash suffered a loss of 0.6 mm or 1.3%. Shaped sycamore showed a slight increase in diameter of 2.1% over the unshaped sycamore.

Discussion

Height

The primary purpose of formative shaping is to improve early stem quality. The reason for examining its impact on height growth is to assess whether shaping had any undesirable effect on overall tree growth. In this experiment, formative shaping had a significant positive effect on the height growth of ash, sweet chestnut and sycamore. There was no significant effect on any of the other species. Of the above three species, ash and sycamore are the most important. As shown in Part 1, they are also two of the species whose quality is significantly improved by formative shaping. Thus, the net effect of formative shaping on two of Ireland's most important broadleaf species is positive for both quality and height growth.

Within the shaped treatment, leading shoots which were naturally apically dominant or which had been formatively shaped concentrated height growth into a single leader and thus maintained dominance in one shoot. Trees with a single stem then put on greater height growth than trees with forks or competing codominant shoots.

Sweet chestnut produced the greatest percentage height increase in response to formative shaping. Unshaped individuals tended towards a globular, bush-like form, with numerous branching shoots, none of which seemed to possess the ability to become a dominant leader. Formative shaping, however, concentrated the height growth onto one single leader, thus forcing dominance on one shoot. The result is a discrete, if not very high quality, single stem, which puts on greater height growth than the multiple stems of the unshaped trees.

Formative shaping had a positive but not statistically significant effect on the height growth of beech. The performance of beech was initially poor, mainly due to the quality of the transplants, but it went on to become one of the most impressive performers on this difficult site. This is possibly due to the developing presence of side shelter created by taller ash and sycamore components of the mixture.

Diameter

Shaping is concentrated on the upper portion of the developing crown and on disproportionately large side branches, in an attempt to maintain one single apically-dominant shoot. While improving tree form, the removal of large side branches or clusters of codominant shoots may have an appreciable effect on diameter growth. Branches only affect the stem below their intersection point with it. Their removal may therefore reduce diameter growth of the stem below the intersection.

Formative shaping had a significant negative effect on the diameter growth of ash, cherry, sweet chestnut, sycamore and walnut. While a significant negative effect was recorded for both ash and sycamore, the actual difference was small. When only Categories 1 and 2 trees were examined, formative shaping had a positive effect on diameter growth in sycamore, suggesting that diameter growth of good quality sycamore stems is improved by shaping. As initial diameter measurements were carried out on transplants under 1.0 m in height, measurements were made at just 20 cm above ground. In order to maintain comparability, measurements were continued at this level for the duration of the experiment. If measurements were taken at 1.3 m, a different result might emerge for cherry, ash and sycamore, as many of the unshaped trees had forked below this level. This fact must be taken into consideration when assessing the diameter results.

While there was no significant effect on the diameter growth of pedunculate and sessile oak, there was an effect among Categories 1 and 2 trees combined, with those stems in the unshaped treatment which managed to maintained single leaders putting on diameter growth. This diameter growth was greater than that on trees in the shaped group, which were being forcibly maintained in the better quality categories by the removal of defects. With both species of oak, it was necessary in some cases to remove considerable amounts of branch material during shaping to produce any type of distinct leader. There is, therefore, a question regarding the best time to commence shaping in oak. There is a tendency for newly planted oak not to produce a discrete leading shoot for a number of years after planting. It may therefore be more advantageous to wait until a definite leading shoot is produced, and then to favour this shoot by shaping. Thus, with oak, it may be better to wait until the new crop begins to put out discrete leading shoots, rather than commencing the treatment when trees are between 1.0-1.6 m in height. It is, however, impossible to predict in which year after planting a plantation of oak will begin to 'shoot' discrete leaders. Therefore, from this experiment, it does not seem possible, as yet, to recommend a specific year or a specific height as the optimum time to commence formative shaping in oak.

Some species, most notably cherry, have a tendency to produce whorls of very heavy branches. In addition to formative shaping, therefore, the early removal of these heavy branches is also necessary to enhance quality. Hubert and Courraud (1987) indicate that not all large branches in a whorl on cherry should be removed at the same time. Rather, removal should be staggered over a number of annual shaping sessions.

While overall diameter growth was slightly reduced by formative shaping, this reduction must be offset against the improvement in form and quality of several species. The clean shaped stems also greatly reduces the diameter of the potentially defective core, compared to stems subjected to later pruning or allowed to self-prune naturally. The reduction in the defect core contributes to the overall value of the stem. While statistically significant, the reduction in diameter growth can be regarded on balance as a small price to pay for the increase in overall stem quality within the shaped group.

Conclusion

The purpose of this experiment was to determine the benefits, if any, of formative shaping. Part 1 (Bulfin and Radford, 1998) describes the positive effect of formative shaping on stem quality. Part 2 assesses the impact of formative shaping on height and diameter growth. Three species benefited significantly in height growth from formative shaping, two of which, ash and sycamore, are among Ireland's most important broadleaf plantation species. Although high quality sycamore stems did experience a slight increase, in general, shaping resulted in a reduced diameter growth after four growing seasons in all species. In practical forestry terms, however, the amount of reduction was not silviculturally important. Of more importance to the potential overall value was the reduction by early shaping in the extent of defect core. In general, formative shaping should begin as early as possible in the rotation, preferably when the trees have reached 1.0-1.6 m in height. The overall conclusion of this study is that formative shaping has a beneficial effect on all eight broadleaf species studied, with very significant benefits being conferred on ash and sycamore. The case for early formative shaping of oak requires further consideration.

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Landscape planning and design for Irish forestry: Approach and model proposed

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Abstract
The afforestation programme in Ireland over the next 30 years is aimed at increasing forest cover from approximately 9% to 17%. Given the frequency of adverse impacts upon the landscape arising from forestry, particularly large-scale commercial plantations, measures such as planning and design guidelines and strategies which ensure overall positive results and avoidance of damage, are urgently required.

Focusing upon landscape issues, this paper outlines the complexity of forestry problems in Ireland, identifying the need for an approach to forest landscape planning and design. A detailed literature review is used as a basis to develop such an approach, emphasising the importance of landscape assessment based upon landscape character typology. Arising from this, a 2-part model is proposed, the first part concerning guidelines developed for nationally generic landscape types, and the second concerning strategies for specific landscape character areas applied to counties. The three main components of this model are examined: forestry capabilities; landscape aesthetic character enhancement potential; and landscape values with their sensitivities. The first two components provide the basis for a proactive approach to forestry, and the third introduces the constraining or qualifying influence.

As far as landscape is concerned, forests can be a major force in landscape enhancement and a medium for the aesthetic experience of nature. It is very important to rise to the challenge by developing forestry in Ireland in a way which is decisively proactive.

Keywords: Forest landscape planning and design, forestry guidelines and strategies, landscape assessment, forestry capabilities, landscape aesthetic character enhancement potential, landscape values with sensitivities and constraints

Introduction
Forestry, particularly large-scale commercial plantation forestry, can have a significant adverse impact in terms of, for example, landscape aesthetics, environment and culture. Increasing public concern over the effects of forestry cannot be ignored by either policy makers or practitioners. Appreciation of the potential for landscape enhancement by forests seems limited among the public and even among many foresters. In order to optimise its impact on the landscape, therefore, more clearly defined strategies and guidelines specifically for forestry which attempt to lead positively towards the realisation of this potential, are required.

The need to develop an approach to forest landscape planning and design in Ireland is highlighted by the emphasis of recent key policy statements, legislative changes and guideline recommendations concerning forestry and the environment, including the national strategic plan for forestry (Department of Agriculture, Food and Forestry, 1996). In January 1997, the Department of the Environment published a report entitled *Forestry Development - Consultation Draft of Guidelines for Local Authorities* (Department of the Environment, 1997). These draft guidelines dealt with the role of planning authorities in relation to commercial forestry, and emphasised the following:

- the urgent need to prepare maps indicating areas within each county which might be regarded as being 'sensitive' in relation to forestry development;
- consideration of the need for an indicative forestry strategy for each county;
- notification to the Forest Service of areas which may be particularly sensitive to clearcutting, and consideration of whether marginal forest sites should be replanted or left to revert to their original state; and
- the intention of the Department of the Environment to introduce more flexible control enabling planning permission to be required for afforestation projects not requiring an environmental impact assessment.

The danger with the above call from the Department of the Environment is that each local authority would proceed to develop forestry strategies independently without a common methodology or procedure. To ensure a rational and nationally effective approach, a structure comprising a single methodological basis is required. The criteria by which analysis is carried out and standards by which evaluation and decisions are made should be applied nation-wide, with due allowance for regional aesthetic, biophysical, social, infrastructural or economic variations. To be effective in practice, the distinct roles played by the Forest Service and local authorities, and their relationship in forestry development, must also be clearly defined and balanced (Environmental Resources Management, 1998).

There is a need to develop a tool for forest landscape planning and design strategies and guidelines, and to provide an administrative framework in which these can play their intended role. Forest planning and design strategies and guidelines can provide national guidance to ensure that appropriate standards are understood and implemented to achieve a cultural, environmental and economical balance. They would provide administrative authorities, forest managers, planners, non-government organisations (NGOs) and other interested parties with a common, adaptable reference base. Technical back-up for this is already being put in place, with the development of the Forest Inventory and Planning System (FIPS) and a national forestry inventory and county-by-county indication of species potential. This paper broadens the scope by highlighting key issues pertaining to the development of an integrative landscape component of a national forestry strategy and guidelines. It examines the spatial planning and design of forestry primarily from a landscape aesthetic perspective understood in the broadest sense.

First, however, it is necessary to identify the many landscape-related problems of forestry in Ireland, in order to illustrate the complexity of the task involved in formulating a forest landscape planning and design model. This will be followed by a review of publications relevant to planning and design, which will help to identify key factors and to direct methodological development.

The problem in Ireland – forestry starting from scratch

Unlike developments such as transmission lines, forestry has the potential to significantly contribute to landscape enhancement. In order to ensure this, however, ways in which plantations have adversely affected the landscape should be recognised. These are not limited to purely visual concerns, but extend to embrace the broader scope of landscape aesthetics. These problems are listed below, not to suggest the inappropriateness of coniferous plantations in Ireland, but to highlight the challenge to be met by forest planning, design and management:

- the sensitivity of many forested landscapes in upland and moorland areas;
- visual fragmentation of the landscape by forest blocks with inadequate integration;
- weakening of landscape character and obliteration of characteristics;
- visual conflict of forests with their contexts in scale, configuration and composition;
- submergence of amenity and cultural features;
- scarring of the landscape by management operations such as forest road construction and harvesting;
- abruptness of change due to clearcutting;
- visual obstruction between, and isolation of, remote rural dwellings;
- cultural failure to understand and appreciate forests;
- shift from the traditional images of Irish landscapes;
- ecological damage concerning, for example, water, soils and biodiversity; and
- infrastructural limitations, possibly causing road damage and traffic hazards.

Distinction between forest landscape planning and design

Forestry strategies can prove important for planning by providing an indication of appropriate use of resources in any given district, including the identification of important environmental, cultural, landuse, aesthetic and social values. They should address forest landscape planning in the spatial sense, being essentially concerned with the effects of forests and forestry practices on landscape, particularly in regard to character and quality. Strategies should also include forest design, indicating the desired appearance of the forest in relation to its context, and incorporating silvicultural and management implications.

This distinction between planning and design in forestry is not always explicit or effectively used by forestry authorities. A similar distinction between the two concepts has been recognised by the Forestry Commission (Campbell and Fairley, 1991), but it does not seem to have been developed systematically into an integrated structure for the control of forestry development. A recent publication by the Forestry Authority (Bell, 1998) also incorporates these terms. But planning is used at a finer scale than that defined above, and would need to be increased and the criteria and implications more fully explored, in order to become effective for the type of planning defined in this paper.

Literature review

Much material pertaining to forest landscape planning and design has been published internationally over the past decade. The following review functions as a framework or scaffold for the construction of a model for strategic forest landscape planning and design and guidelines. The review studies indicative forestry strategies and landscape assessments which can provide the necessary methodological foundation. Material relating to guidelines is more limited to design, and includes guidelines, training manuals, handbooks, codes of best practice, forestry standards and public surveys.

Indicative forestry strategies

Indicative forestry strategies, involving the designation of *preferred*, *potential* and *sensitive* landscape categories, have been produced during the past few years by several Scottish regional authorities, including those for the Tayside, Strathclyde, Highland and

Grampian regions, but have come under considerable criticism (Stuart-Murray, 1994; Sidaway and Turnbull Jeffrey Partnership, 1997, cited in Environmental Resources Management, 1998). Firstly, indicative forestry strategies have tended to adopt a conservative and restrictive approach, resulting from the assessment of sensitivity as a priority without seeking positive opportunities for forestry. Secondly, areas deemed to be *sensitive* are often planted, while those in the *preferred* category are often not (MacMillan, 1993). Thirdly, inconsistency exists between regions in the methodologies employed and resulting designations. Fourthly, there is little evidence of the use of indicative forestry strategies during consultation on afforestation grant applications or in the provision of advice on local sensitive areas with planning authorities.

A draft indicative forestry strategy developed by Wicklow County Council (1997) offers an Irish example. This strategy also seems to treat forestry purely as a sensitive issue, rather than accepting it as being potentially positive for the landscape. Such reservation is understandable, given the poor design of existing plantations and concerns with water quality in areas where rock and/or soils are acidic. Nevertheless, instead of searching for opportunities for enhancement, the strategy seems to adopt a defensive position. The blanket stipulation of distance limits to roadsides and elevation thresholds on mountains for certain parts of the county are both examples of caution which may have arisen from a lack of knowledge about forestry in general, and from a reaction against the plethora of existing poorly integrated forests. Ironically, in regard to this latter point, as well as being the most afforested county in Ireland, Wicklow contains some of the better examples of design.

Landscape assessment and character

A fundamental basis for forest landscape planning and design is landscape assessment methodology. This can provide a thorough understanding of the landscape and help to identify opportunities for enhancement and creative alteration. A considerable portion of the review provided below will draw from work carried out in the UK. This is due to the overall maturity of its landscape assessment strategies (Environmental Resources Management, 1995), landscape similarity and linguistic accessibility.

Initial exploration of the potential of more pragmatic science-based criteria involving land classes, such as those developed by the Institute of Terrestrial Ecology (ITE) in Britain or by Cooper and Murray (1992) in Northern Ireland, resulted in recognition of the importance of visual interpretation. This allowed for assessment of landscape visual character, which in turn provided the basis for strategic landscape planning and designation. This has been affirmed in the methodological guidance for landscape assessment produced by the Countryside Commissions for Scotland (Land Use Consultants, 1991a) and England (Cobham Resource Consultants, 1993).

An important distinction was made in the Warwickshire Project by the Countryside Commission (1991) between *landscape character types*, which are generic, and *landscape character areas*, which are geographically specific examples of these. This project, along with studies relating to the Blackdown Hills (Cobham Resource Consultants, 1989), the Cotswolds (Cobham Resource Consultants, 1990), the Cambrian Mountains (Land Use Consultants, 1990), the North Pennines (Land Use Consultants, 1991b), Northamptonshire (Cobham Resource Consultants, 1992a), the Tamar Valley (Cobham Resource Consultants, 1992b), the Forest of Bowland (Woolerton Truscott, 1992a) and the Cleveland Community Forest assessment (Woolerton Truscott, 1992b), involved landscape character established by visual analysis of physical features including the history of landscape evolution, such as geology, geomorphology, landuse alterations and cultural interpretations throughout time. These factors have since become the hallmark of landscape assessment in the UK.

While guidance produced by the Forestry Authority for England on the preparation of indicative forestry strategies (Price, 1993) emphasised the need to respond to existing visual character, it lacked development into an approach to positively change this character. Notwithstanding this, landscape character has proved useful for forestry strategies. The Great North Forest assessment (Land Use Consultants, 1992) and the Staffordshire (Murray, 1995) and Central Scotland (Central Scotland Countryside Trust, 1995) forestry strategies have each taken a step towards landscape typological guidance for forestry. They have identified afforestation opportunities for specific landscape character areas in relation to different woodland types.

Landscape character types can also be considered as a basis for forest landscape planning and design guidelines. The Forestry Authority in Scotland is currently developing landscape character-specific woodland design guidance for the Dumfries and Galloway regions (Environmental Resources Management, 1997), involving a listing of opportunities and constraints and an indication of appropriate design response. The approach is useful in principle for the development of national landscape typological guidelines. Having conducted an on-the-ground examination of the Dumfries and Galloway regions in Scotland, it is the opinion of these authors that the scale of landscape character areas used in the above forest landscape design guidance is too fine, resulting in unnecessary repetition. It is important to ensure sufficient detail on one hand, and the avoidance of repetition and superfluous distinctions on the other.

Hierarchical structure for national and regional levels

The importance of a hierarchical structure for landscape assessment, strategies and guidelines has been recognised in studies such as the Warwickshire Project (Countryside Commission, 1991). One of the main conclusions of that project's pilot study was the need to adopt a strategic rather than a small-scale farm-based approach to landscape assessment, in order to establish a framework within which more detailed landscape studies could be based. This has also been affirmed by the delegates at the conference reviewed by Moore (1998), and also by Diacono (1998), who highlights the need for a strategic framework within which the assessment process across the tiers of local authority can be co-ordinated. Such a structure would help to overcome the problem of incompatibility and inconsistency between different assessments and assessors.

Even within the broad categories of upland and lowland, the UK forest landscape guidelines (Forestry Authority, 1994; Forestry Commission, 1992a; Lucas, 1991) succeed in covering a considerable variety of landscapes in relation to visual response. But while landscapes such as plateau moorland or drumlins may correspond visually to the generic flat or hilly landforms included in those guidelines, their ecology involving soils, hydrology and vegetation, as well as their cultural meaning in terms of landuse, history, image and aesthetics, are quite distinct. Of equal importance is the difference in species potential and silvicultural systems possible between such landscape types. Some degree of typological distinction, therefore, could provide more direction to forest designers and managers without necessarily compromising flexibility. Swanwick (1998) suggests that a hierarchy of common guidelines could be provided at a broad character area level, with more specific guidelines at the level of generic landscape type, and some at the more local level.

In essence, therefore, a hierarchical approach to landscape assessment for forest landscape development is important to ensure correspondence between both planning and design, and to provide a procedure which educates foresters and planners to understand landscape and its assessment. This can comprise national guidelines based on generic landscape character types, and county strategies involving a methodology for landscape-specific assessment and application of these guidelines.

Integrative approach – the science, art and culture of forest landscape

Unlike many other types of development, forestry comprises natural material and processes which can be scientifically determined. The Irish national forestry strategy (Department of Agriculture, Food and Forestry, 1996) fails to address these adequately, whether concerning nature conservation or the value of new landscape and habitat creation (Environmental Resources Management, 1998). Landscape in terms of such scientific factuality must be complemented by the realisation of its complex reality as a palimpsest of historical and cultural overlays. This is apparent when studying the effects of forestry on archaeology, as well as recreational and functional meaning, from which a more complete aesthetic experience is derived.

Thus, landscape assessment methodology should be integrative (Warnock and Brown, 1998a; Swanwick, 1998). *Characterisation* has been used in the UK, specifically by the Forestry Commission and Countryside Commission, to broaden the basis of landscape assessment to include aspects of a landscape area other than the visual. Methodologically, however, characterisation has not been used effectively for either planning afforestation (Environmental Resources Management, 1998) or in achieving an "integrated treatment of different environmental domains" (CAG and Land Use Consultants, 1997).

UK forest design guidelines (Forestry Authority, 1994; Forestry Commission, 1992a; Lucas, 1991) have opted for a visual basis without due regard of their interrelationship with nature conservation, recreation, water and archaeology, which are all dealt with in separate guidelines (Forestry Commission, 1990 & 1992b; Forestry Authority, 1993 & 1995). The forest design guidelines produced by Ireland's Forest Service (1991) are equally narrow in their focus on the visual, as well as being general and superficial. Considering the imminence of landscape transformation through forest plantation and management practices in Ireland, more substantial and integrative guidelines are urgently required. This involves consideration, both separately and integratively, of the science and aesthetics of landscape, as well as of landscape values and their sensitivities. FIPS may represent a tool to achieve such integration.

Conservation oriented and/or proactive planning and design

The approach to landscape prevalent in the UK has typically been conservation oriented rather than proactive regarding alteration and development. Even where balance in strategies is aimed for between conservation, restoration and innovative design (Warnock and Brown, 1998b), many of those involved in landscape assessment and planning (Moore, 1998) remain cautious, or even fearful of change. The stronger the landscape integrity, the greater is the tendency to conserve, while landscapes of lesser sensitivity comprising weak character, degradation or low visual exposure might be favoured for 'creative' development. Some forestry strategies, however, have ostensibly moved towards a more positive acceptance of commercial plantations. Examples of these include the Airdrie Woodlands Initiative (Strathclyde Regional Council and the Central Scotland Countryside Trust, 1995), the Argyle and the Firth of Clyde report (Environmental

Resources Management, 1996) and the Staffordshire strategy (Murray, 1995).

In order to ensure a balanced approach to forestry in the landscape, different kinds and degrees of sensitivity must be introduced into the process (Warnock and Brown, 1998a), considering, for example, quality, distinctiveness, popularity, rarity, cultural meaning, representativeness and social use. In their study of Warwickshire, Warnock and Brown (1998b) have established the concept of appropriateness as the proactive basis for assessment, while that of sensitivity introduces the constraining and qualifying influence. The same caution noted earlier is again evident, however, as development seems to be considered for areas without strong landscape character.

While a proactive approach to forestry could be adopted in any country, it would be particularly appropriate in Ireland where, due to a relatively low population density and prevalence of extensive areas of traditional landuse and landscape pattern, regional character is generally intact and not critically threatened with destruction or under pressure for recreational use. Thus, besides constraints based on evaluation of the sensitivity of different landscape values, the approach should consider the enhancement of any landscape by appropriate aesthetic response to its character and pragmatic or scientific capability.

Adding the why, how, how much and to whom to the what of character

The concept of a more integrative characterisation which reflects coherence across a range of environmental topics has recently emerged in the UK. For example, the so-called environmental capital approach (CAG and Land Use Consultants, 1997) recognises the need to simultaneously address a host of factors which affect the "features and characteristics" of the environment in relation to sustainability. It attempts to broaden the basis of assessment to consider, not simply the *what* of landscape, but also the *why*, *how*, *how much* and *to whom*, by identifying the benefits which these features and characteristics provide in terms of "attributes, services and functions". These in turn provide the basis for evaluation and consideration of their substitutability. Incorporation of the latter is key in attempting to overcome the conservative conservation-oriented ethos. It ensures flexibility in allowing a proactive openness to development on the grounds of gains and losses of, for example, characteristics and attributes considered from the local to the global scale. There is considerable scope in the environmental capital approach for methodological investigation, development and adaptation in regard to forestry.

Common approach comprising purposeful planning and design criteria

The visual design principles listed in the UK (Forestry Authority, 1994; Forestry Commission, 1992a) and British Columbia (Forest Service, 1994) publications are ambiguous in regard to their role. Principles such as shape, visual force and scale seem to be design tools, while diversity, unity and spirit of place are more like design objectives. Furthermore, scale is ambiguously applied in the sense of extent of forest cover and also more intimately in the sense of proportion. Rather, it would seem logical to establish a set of principles as tools to achieve specific aspects of desired forest landscapes.

The establishment of a common methodological approach to forest planning and design is important in Ireland, given the relatively compact county administrative areas and the continuity of landscape types from one county to the next. Indicative designations concerning forest landscape planning and design could be produced for the Forest Service where this would be related to other factors affecting forestry, such as land value, and become accessible to interested parties through FIPS. When application is being made for forestry development, the planning and design guidelines, comprising criteria with application adaptable to each landscape character type, could serve as an important consultation medium for all parties concerned. In particular, they could help to bridge the knowledge gap between foresters, planners and landscape experts.

Flexibility of planning and design response

In relation to design, guidelines invariably encourage naturalistic forest design (Forestry Authority, 1994; Forestry Commission, 1991 & 1992a; Ammer and Pröbstl, 1991; Lucas, 1991; Udgivet af Skov, 1991; Logging Industry Research Organisation, 1993; Forest Service, 1994 & 1995; USDA Forest Service, 1995). In reality, however, this may not always be feasible or necessary, especially in Ireland where little forest context exists or where extensive areas of landscape are strongly characterised by human use and rectilinear pattern. Regarding planning and design, guidelines should reflect reality by depicting the impact of different areas of cover on any given landscape character type, in particular tiny 'postage stamp' plots in open areas, and how this impact can be mitigated and exploited aesthetically. Furthermore, strategies and guidelines should not only contend with afforestation, but also with restructuring existing forests, many of which will not meet new aesthetic standards. They need to be flexible and realistic, being performance-based rather than prescriptive, and indicatively suggesting planning and design solutions to typical problems.

An Irish approach to forest landscape planning and design

In developing a tool for forest planning and design based upon the above review concerning strategies, assessment and guidelines, key recommendations are listed below as the basis for an Irish approach.

1. Develop a common methodology for assessment, forest planning and design.
2. Provide a medium for consultation and education through strategies and guidelines.
3. Distinguish criteria and factors in relation to forest planning and design.
4. Identify landscape character types/areas as the basis for assessment and designation.
5. Establish a hierarchical approach to landscape assessment, planning and design.
6. Ensure comprehensive integration of the science and art of forestry.
7. Aim for balance between proactive drive and constraint.
8. Strategies and guidelines to be indicative and performance-based, not prescriptive.
9. Be realistic rather than idealistic, by contending with typical and difficult problems.
10. Improve existing forests to meet new aesthetic standards.

Essentially, the approach to forest landscape planning and design being proposed comprises landscape character areas, determined by a process of integrative characterisation, as the basis for assessment in regard to the following three key components:

- scientific forestry possibilities;
- landscape aesthetic enhancement potential; and
- sensitivity of landscape values.

The first two of these components provide the proactive vision of landscape alteration and development by forests. The third component introduces the braking action, qualifying the acceptability and type of forestry appropriate to a given location. The key is to temporarily postpone consideration of landscape sensitivity and focus initially upon landscape character and its potential for enhancement. This separation is important: instead of considering forestry for a given landscape on a *posteriori* basis (i.e. as a result of an initial landscape assessment deeming various values of sufficiently low sensitivity), it considers it on an *a priori* basis, whereby the potential for landscape character enhancement is prioritised. In light of the above review, such an unambivalant acceptance of the potential of forestry for landscape enhancement would be a departure from the current approach to landscape assessment and planning.

Proposed forest landscape planning and design model

This paper will now proceed to propose two models of forest landscape planning and design. The first model (Figure 1) outlines the basic relationships between its three components: the assessment of landscape physiography to scientifically establish its forestry capabilities; landscape aesthetic character to determine enhancement potential; and the sensitivity of different landscape values to indicate the need for the introduction of constraints and qualifications.

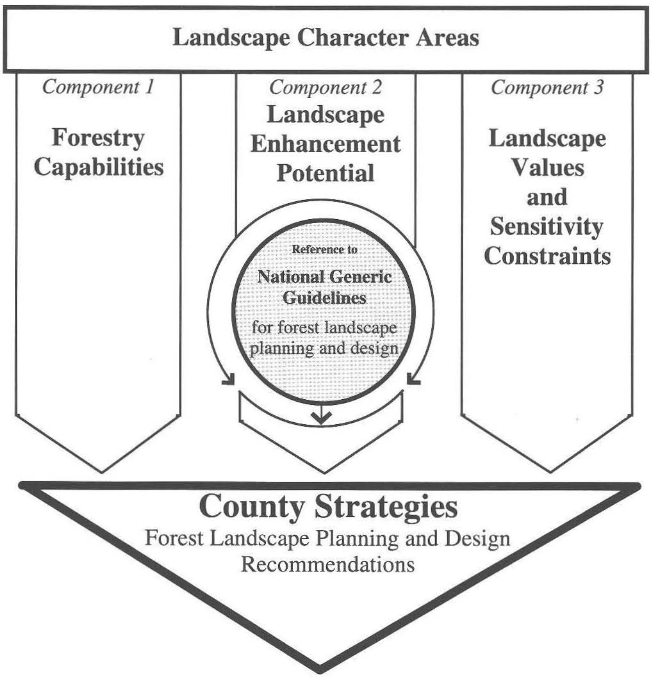

Figure 1. *Simplified model for forest landscape planning and design.*

The second model (Figure 2) elaborates upon the first and is structured in two parts comprising guidelines and strategies. The models are based on a foundation of landscape character typology. They involve the integration of the three components, the first two providing the driving mechanism by proactively identifying pragmatic capability possibilities and landscape character enhancement potential of forestry, and the last component introducing constraints.

The first part of the more complex model depicts a methodology for forest landscape planning and design guidelines to be developed generically at a national level. The second part comprises a more complex methodology for forest landscape strategic planning and design pertaining to specific landscapes, such as that at a county scale. Production of strategies depends upon the guidelines as an indication of preferred solutions. While the three components listed above are relevant to both parts of the model, only landscape enhancement potential is of primary concern for the guidelines, the other two components being considered generally and typically. For this reason, the paper will focus upon the second, more complex, part of the model concerning the production of forest landscape planning and design strategies. The model establishes the respective autonomy of each of its three main components, orchestrating when and how they interrelate to achieve balanced forest landscape planning and design strategies for landscape character areas.

Character area identification

In order to develop a landscape planning and design model, it is necessary to attempt to grasp how man understands the landscape and how this can be systematically incorporated into a methodology. The process of landscape assessment for systematic and methodological clarity can correspond to three levels of understanding, moving from the quantitative to the qualitative. All of these levels might be used to determine a landscape character area, but typically either the first or a combination of the first and second may be more useful for initial forest landscape planning and design. These three levels of understanding are described below.

1. The first level produces physical units and concerns physical features, including geology, soils, vegetation, landuse, elevation and climate, which provide the basic data for an initial desk study breakdown of landscape. Whether natural or cultural, such factual character can be determined by considering landform and landcover. Features could include those at the micro-scale, such as the flora of the Burren, but would more typically include larger scaled elements such as topography, hedgerows, copses and woods, watercourses and roads.
2. The second level produces physio-visual units. It builds upon the first and broadens the scope to allow for actual visual experience, i.e. perception of physical units within larger landscape contexts. This physio-visual level combines distinction in relation to physical features with viewshed. While the character areas identified at the second level may typically prove adequate for planning and design, due consideration should also be given to other ways of reading the landscape.
3. Thus, at an even broader, albeit more complex, level, the apprehension of landscape is considered, involving meaning to produce characterised units. This includes typical public apprehensions or image of the landscape, as well as popularly perceived characteristics such as function, openness, accessibility, tranquillity and historical associations. At this level, landscape characterisation, which is concerned with the sustainability of place identity understood holistically, becomes particularly important.

Environmental features and characteristics are specifically identified for each of the three components of the model, but continue to emerge and accumulate as the process

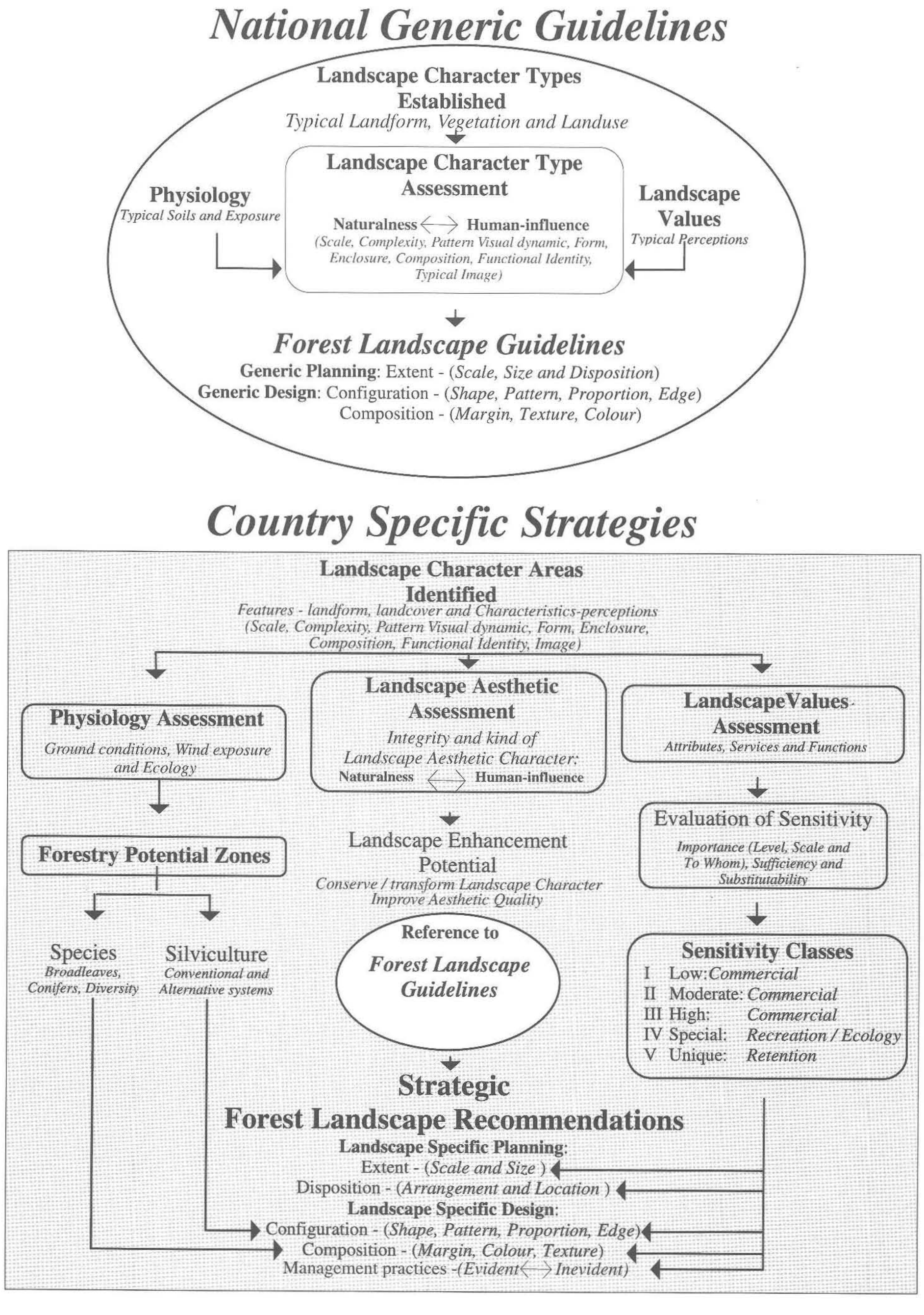

Figure 2. *Forest landscape planning and design model.*

moves from one to the next. This process starts with the physical environment in the first component, expands to reflect aesthetic apprehension in the second, and broadens in the third to include other characteristics not previously covered, as well as considerations such as the relative importance, meanings, values and associations attached to these characteristics. Thus, the proposed model gradually unfolds, being consummated in the production of forest landscape strategic recommendations concerning planning, design and management.

Assessment of landscape with respect to its character and characteristics can be subtle and complex. As the assessment process is ultimately integrative and concerns a landscape perceived as a whole and as a continuum, it is important to identify key criteria despite the abstraction and apparent autonomy of each. Together, these criteria should reflect the process of landscape character and characterisation assessment outlined above. Among these criteria, the following are particularly important:

- *scale*, concerning the visual extent as perceived and is determined by complexity and size of landform;
- *complexity*, concerning the variation of landform, vegetation and landuse throughout the landscape;
- *pattern*, addressing the superficial appearance of the landscape, as determined by, for example, vegetation, rock, water and landuse;
- *visual dynamic*, concerning the generation of a sense of spatial and formal flow;
- *enclosure*, concerning the sense of containment or openness;
- *form*, regarding the shape of land mass;
- *composition*, providing for the possibility of different units of physical character being seen together, so forming a new whole viewshed character;
- *functional identity*, derived from the apparent use of the landscape; and
- *image*, reflecting cognitive response and the spiritual sense (for example, a mountain moorland typically signifies a place of remoteness and wildland character quite distinct from that signified by a green patchwork agricultural landscape).

Examples of landscape types relevant to forestry in Ireland are as follows:

- mountainous moorland, e.g. Wicklow Mountains and the Twelve Bens;
- rolling hills with agricultural mosaic, e.g. Wicklow and Wexford agricultural land;
- plains with agricultural mosaic, e.g. plains of Tipperary and north Cork;
- plains of moorland (including cut-away bogs), e.g. peatlands of north-west Mayo; and
- drumlins with agricultural landcover pattern, e.g. Leitrim, Cavan and Monaghan.

Model Component 1: Physiographic assessment for forestry capabilities

The capabilities of a landscape for forestry are primarily dependent on physiographic factors of landscape which are objectively determined and scientifically assessed. While the landscape character areas already established are likely to include more than a single physiographic unit, they will nevertheless provide a basis for the physiographic assessment, thereby maintaining methodological consistency. This physiographic assessment involves the pragmatic and science-based approach of the forester who, taking landform and vegetation as primary indicators, establishes exposure and soils in order to determine the species and silviculture for which the land is capable. But while forest site types have conventionally been identified based upon physiographic (geology, topography and aspect), edaphic (soils and drainage) and climatic (rainfall and frost) conditions, if environmental sustainability is being sought, it is necessary to broaden the basis to include ecology.

The result of this assessment is to break down landscape character areas into zones of capability for different forest species and silvicultural systems. This would include not only species for commercial production, but also for biodiversity. Silvicultural systems would include the 'classical' systems of clearcutting, group selection, shelterwood, strip system, single tree selection, agro-forestry, short rotation coppice and combinations of these, as well as more ecologically sympathetic systems such as native and semi-native woodlands and the mimicking of natural disturbances. At this stage in the development of forestry in Ireland, consideration of many silvicultural systems at the county level would prove almost impossible, due to the lack of sufficient experience. Rather, it is more realistic to carry this out at the site level. Nevertheless, with time and experience, this factor of the pragmatic side of the model should be more attainable.

Where forestry capabilities have not been realised with existing forests, the zones will also have implications for restocking. The provision by forestry capability zones of the option to redesign existing forests for improvement represents a major opportunity for Irish forestry during the coming decades.

In relation to administrative control of forest landscape planning and design, the objective here is to establish an objective 'open book' of actual land capability for species and silviculture. This would be particularly useful to non-foresters such as planners, landscape experts and NGOs, who would otherwise have to struggle without sufficient technical expertise. It thus becomes a necessary starting point for all interested parties, whether investor, forester, planner or landscape designer. But rather than attempting to provide a categorical and definitive classification, it would be general and indicative.

Model Component 2: Landscape aesthetic character assessment for enhancement potential

Complementary to the scientific capabilities for forestry in a given landscape is the potential for alteration and aesthetic enhancement of landscape character by forests. This potential is identified during the assessment process. Recommendations in regard to enhancement would be facilitated by reference to, and adaptation of, generic landscape typological guidelines. The latter guidelines, as indicated in the model, would be developed independently of the strategic assessment.

The physical features and characteristics of landscape identified earlier in establishing landscape character areas can now be assessed to gain the understanding necessary for such alteration and enhancement in relation to planning and design. This can be achieved to some degree by using visual criteria similar to that employed by the USDA Forest Service (1995), the Forestry Authority (1994) and the Forestry Commission (1992a), involving various ways of interpreting landform and landcover analytically. It is, however, the sum of the parts which gives the sense of landscape and its integrity of character, and which provides the grounds for a sympathetic forest landscape planning and design response (McCormack and O'Leary, 1995). For now, an understanding is sought of the particular visual expression which the physical indicators give as perceived within a viewshed from the ground in each landscape area. While the criteria previously used to determine landscape character areas (i.e. scale, visual dynamic, complexity, pattern and image) would be used to examine the landscape in relation to its aesthetic quality and integrity of character, subjectively apprehended landscape meaning should also be interpreted as part of the assessment process.

Indication of the potential for landscape enhancement by forestry is expressed in landscape spatial planning and design terms. More fundamental from a planning perspective is the capacity of landscape types to absorb forestry without loss of character integrity. This capacity is determined by complexity of landform and landcover. Alternatively, the possibility of changing the existing landscape character by forest cover to produce a new character, can be considered. The criteria proposed for forest landscape planning are *extent* (involving the factors of *scale* and *size*) and *disposition* (involving the factors of *arrangement* and *location* of forests within the visible landscape). The greater the extent of cover, the greater the probability of landscape character transformation. Whether small, medium or large, the scale of cover is a function of the scale of the landscape concerned. What seems large in one, therefore, may not be so in another. For example, a forest of 69 ha, just below the threshold for an environmental impact statement, would completely cover a valley such as Glenmacnass, Co. Wicklow. Meanwhile, smaller areas of afforestation can incur a very significant adverse impact upon large-scale open landscapes, depending upon size and disposition in the landscape.

Complementing a strategic approach to forest landscape planning is the design of individual forests, concerning the degree of contextual integration as well as whether the forest is natural or human-influenced in design expression. As part of the assessment process for the strategy, therefore, an indication of a number of enhancement possibilities would be made for each landscape character area articulated using the criteria of forest *configuration* and *composition*. Configuration covers the design factors of *shape*, *pattern*, *proportion* and *edge*, while composition covers *margin*, *texture* and *colour*.

It should be recalled at this point that, with the development of the planning and design guidelines independently, a selection of prototypical scenarios based on landscape character types, comprising a range of possible solutions, would be available as the 'touch stone' against which the specific landscapes being assessed can be related. These should not be regarded as prescriptive, for flexibility of choice is important both as a matter of principle and for practicality. Regardless of an intrinsic tendency within a given landscape character type towards the naturalistic or the human-influenced, interpretation and adaptation of forest landscape guidelines are inevitable in response to a host of possible variables.

The forest planning and design criteria and their factors are defined below. They are the tools in the forest planning and design process for responding to landscape character and determining design expression. Finer qualification would also be made depending on the sensitivity of the area, as discussed later (Tables 1 and 2).

Planning criteria

Extent (landscape character capacity to absorb change): Extent contends with the amount of forest cover in the landscape relative to the overall visible distance. It is the criterion for the control of afforestation in relation to the alteration of existing landscape character, and comprises:

- *Scale:* Overall area of forest cover, expressed as a percentage in relation to the openness of landscape (landscape character type or viewshed), as determined by landform complexity. It is a major determinant in regard to the preservation or obliteration of existing landscape character.
- *Size:* Area of individual forests. The greater their area, the more likely they are to coalesce into continuous units and so affect the perceived visual dominance.

Disposition (articulation of landscape character): Deposition focuses on where forests are in the landscape and how they spatially relate to each other. It comprises:

- *Arrangement:* Spatial relationship of forests throughout the landscape relative to one another, ranging from the unitary to the scattered. This will determine whether the character is one of continuous homogeneity or piecemeal. It will especially affect landscape visual dynamic or flow, as well as continuity of landcover.
- *Location:* Position of a forest or forests in a landscape, providing visual structure and articulation to certain parts of the landscape character concerned. For example, the location of forests on a valley floor and perhaps extending up part of the adjoining slopes may prove optimal in terms of silviculture, practical regarding management, and enriching from both an ecologically and aesthetical perspective.

Design criteria

Configuration (spatial structure and silviculture): The criterion of configuration shifts the focus from relative extent of forest cover to the intimate design of the forest itself as part of the landscape. It is concerned with the aesthetic relationship of the forest, both the overall mass and compartmental subdivisions, to context, and comprises:

- *Shape:* Outline of the forest or the forest footprint, ranging from organic curvilinearity to geometric rectilinearity, and concerning the plantation externally as an overall mass and internally in relation to compartments, as defined by roads, rides, fire breaks and clearings.
- *Pattern:* The combination of canopy and clearings (or solid to void), and their relative area and disposition, involving, for example, deer lawns and open areas for roads, rides and fire breaks.
- *Proportion:* Size of constituent components of the forest relative to those of the surrounding landscape, involving compartments or blocks as might be delineated by roads, rides and fire breaks, and also clearings, projections and recesses.
- *Edge:* The juncture of the plantation and open ground, concerning the spatial disposition of trees at both the external and internal peripheries. Edge treatment could range from dense straight to open structured recess and projections, and may include outliers, ranging from straight densely packed edge to loosely formed scattered outliers.

Composition (species selection and species and age structure): This criterion completes the basis for design by establishing the structure and content of the forest canopy, i.e. the species and their location throughout the forest. Here, the forest and the surrounding landscape can be aesthetically blended through species selection and silviculture.

- *Margin:* The peripheral zone with respect to species, whether monocultural or mixed, uniform in height or multi-layered with age class differences and scrub.
- *Texture:* Three-dimensional variation of the canopy surface due to species and age diversity.
- *Colour:* Chromatic variation, whether involving the subtle differences between conifer species or the stronger contrast between conifers and broadleaves.

Model Component 3: Landscape values and sensitivity assessment

To realistically seek ways of encouraging well-designed forests, we require not only a sound basis for developing alternative forest landscape scenarios, but also a means of constraining or qualifying these alternatives. Landscape values, therefore, must be identified and then evaluated regarding the degree of sensitivity to indicate the need for planning and design constraints. Of the three components, it is in the identification and assessment of values that parallels can be drawn with the environmental capital approach (CAG and Land Use Consultants, 1997).

This assessment involves identification and evaluation of environmental attributes, services and functions of the features and characteristics established earlier. It involves both desk studies and field work, using ordnance survey 1:50,000 and 1:25,000 scaled maps as well as amenity maps, national designations, county development plans and special studies and reports. All of these provide an indication of viewer numbers, road class and structure, and information on landform and features, including water bodies. Substantiation of the sensitivity classification may be achieved from national or foreign public survey data (including attitudes, preferences, opinions or behaviour) (McCormack and O'Leary, 1997), local consultation and from poetry, prose and paintings.

Issues pertaining to social sensitivity, for example, could be: the popularity of an area; its educational function or potential; its economic role in the locality or region; the existence value of, and public interest in, the landscape; and social interconnection between remote or isolated houses (McCormack and O'Leary, 1997). Values which pertain more specifically to landscape might be the aesthetic quality, the prevalent sense of nature, representativeness, typological rarity, context, water catchment, tourist routes and log transport links to processing centres. Ecological integrity would also be considered and could be important at the small scale. Cultural use patterns, whether as an existing or historic process, as well as ancient and historic structures such as discrete artefacts, are also values and indicate possible sensitivity. A landscape could be highly valued simply due to the publicly perceived significance of a single structure, such as a pre-historic site or a stately manor house. Areas of significance to the public also include those already designated, such as Areas of Outstanding Natural Beauty (AONBs), Special Areas of Conservation (SACs), Areas of Special Amenity (ASAs), Natural Heritage Areas (NHAs) and Special Protection Areas (SPAs).

Evaluation of sensitivity involves more than simply determining a general sense of importance of the issues concerned. The assessment must also consider, for example, the degree of importance (whether low, medium or high), the scale of importance (whether local, regional, national or international), and the people affected. In addition, consideration should be given to whether there are enough of the attributes, services and functions for both now and the future, and also their substitutability (CAG and Land Use Consultants, 1997). In regard to the latter, assuming, for example, that biodiversity or recreational facilities in an area are important but will be adversely affected by harvesting, the question of whether the loss would be balanced by the provision of the same close by, could be considered. Thus, the concept of substitutability introduces flexibility to the process of planning and design, and this is important for a proactive approach.

While substitution options can be quite precise for a specific development proposal, they will tend to be general for strategies. Furthermore, identification of attributes, services and functions will depend upon the availability of data. Notwithstanding these possible limitations, it is important to introduce into the process the criteria and rigour of application necessary for a thorough and balanced assessment, such as those proposed by the environmental capital approach. With time, data will increase and expertise improve, and the process can be more fully realised.

Sensitivity classes

Five classes of sensitivity are proposed to achieve equanimity towards forestry in regard to strategic landscape planning and design. Together they should also provide a practical framework to which various kinds and degrees of sensitivity can relate, and from which their implications can be determined. These classes are as follows:

Class I – Low sensitivity: Commercial: These landscapes are of low sensitivity due, perhaps, to flat terrain, poor visibility or low public significance, and often comprise fertile and marginal agricultural plains. Commercial forests would be acceptable with relatively few aesthetic constraints. Monoculture and clearcutting would normally be acceptable. In addition, forest roads could be laid out for operational optimisation. In typically flat terrain, the key to success would usually be well-designed external edges, as a screen to sensitive areas adjacent to the site. Particular attention should be paid to public roadsides and the interface with adjacent homesteads. Design emphasis will be on configuration, especially in relation to edge. Typically, forests in these landscapes would be designed by a forest manager with basic training in forest landscape design.

Class II – Moderate sensitivity: Commercial: Landscapes in this class are of moderate sensitivity, likely due to either undulation and elevation of landform or high viewer numbers and public interest. Management practices would involve, for example, phased and contained operations to minimise aesthetic and environmental impacts. Besides including the particular concerns of Class I, the forest in its entirety would be addressed in regard to its relationship with its surrounds as well as its pattern, i.e. the creation of clearings within the canopy. This would also include the location, frequency and direction of forest roads, ride lines and fire breaks. Furthermore, it would encourage species diversity and suggest modest constraints upon thinning and harvesting practices. One fundamental objective would be to ensure that forest landscape design guidelines are adhered to in detail throughout all aspects and stages of the forest rotation, in order to achieve modest impact. Forests in this class would be designed and monitored by a forester with substantial training in landscape design.

Class III – High sensitivity: Commercial: Forests in these landscapes can be commercial but should explicitly provide visual quality. This class would apply to highly sensitive landscapes which are scenically attractive, and also to those which are visually intense such that landform structure strongly defines a viewshed. A clearly articulated valley or deeply incised fjord would be examples of the latter, as would a large dominant mountain standing in relative isolation and commanding the surrounding space. In these cases, it is not sufficient to consider the aesthetic impact of management and species simply within the forest and its immediate context. Instead, one must step back to examine its relationship to the larger landscape context. As the forest must be visually integrated into the broader landscape, consideration should be given to its impact on the landscape as a whole, in relation not only to its design configuration and composition, but also to its planning scale, size and disposition. The objectives would be to ensure that commercial forests and their management practices would respond to the character of sensitive viewsheds, and that their management would reflect very high standards of planning and design. Species selection, silvicultural systems and all aspects of management should come under very careful consideration, in order to avoid adverse aesthetic impact and to ensure enhancement. The forest should not conflict critically with any of the values identified. These forests would be designed and monitored by a forester in conjunction with a relevant professional, such as landscape design or ecology experts.

Class IV – Special landscape: Conservation: Only non-commercial forests providing

recreation or reserves for wildlife would be permitted in this class. Typically, designation to this class would be due to landscape quality, recreational or cultural value, or ecological significance. In many cases, such forests will already be in existence as popular amenities, such as forest parks, or might be zoned, for example, as SACs, NHAs or AONBs. It would be desirable that existing commercial forests at such locations be converted entirely or in part to provide an amenity or a nature reserve, although this has implications for compensation. A strong sense of naturalism would be required in these landscapes, usually involving an abundance of broadleaves. While forests would not necessarily comprise purely native species, diversity would be expected. Typically, these forests would be designed by landscape or ecology experts in conjunction with a forester.
Class V – Unique landscape: Retention: This class addresses landscapes, whether with or without forests, in which avoidable change is not acceptable. This could apply where, for example, national or local authorities as well as public awareness have recognised the beauty or uniqueness of landscape character, or where landuse is of historical or cultural importance. Thus, the concern could be for the preservation of a landscape type for reasons of amenity, cultural or spiritual significance, aesthetic value or ecological uniqueness. This may include, for instance, visually pristine, pure and undefiled barren and treeless landscapes such as an open moorland, or perhaps simply representative examples of landscape types which might be in danger of being lost due to change. The objective would be to retain or, if necessary, restore the essential integrity. In most cases, the landscapes concerned will comprise SACs, NHAs or AONBs. Some landscapes, however, may not be designated yet obviously warrant maintenance to sustain their intrinsic qualities. A forest would be deemed to be an unacceptable intrusion and disruption of existing conditions, and would not be permitted. In such instances, common sense must prevail and a sound understanding or agreement be reached between the deciding parties, namely the Forest Service, the local authorities and, where the land is not public, the private landowner. The legal complexities of precluding afforestation by private owners must be considered against the duty to ensure the preservation for posterity of a variety of landscapes and of special landscape qualities and characteristics.

Strategic forest landscape planning and design recommendations

The earlier identification of landscape enhancement potential, produced from the assessment of the second component of the model, now becomes the basis for the development of forest landscape planning and design recommendations. This potential, however, must be qualified by the other two components concerning forestry capabilities and kinds and degrees of sensitivity. The interaction of the three components of the model is indicated in the lower portion of the model illustrated in Figure 2.

From the results of the physiographic assessment, greater accuracy of design can be achieved in relation to both configuration and composition. The practical implications of the former are directly determined by silvicultural systems, while the latter is considered in relation to species options. The results of the values and sensitivity assessment will influence planning in regard to the acceptability of forestry and, if so, the kind and extent appropriate. Following through from the kind of forestry appropriate, values will also influence design configuration and composition in response to possibilities such as the common perception of the landscape as open, accessible and remote or as a place of work and production, or the degree to which biodiversity is important or cultural values and associations are prevalent. Forestry management practices will also be determined systematically as a result of this integrative process involving the three components of the model. From the first component, certain management practices will be implicit to the silvicultural and species capabilities identified, but their impact in relation to both aesthetics and sensitivity must also be considered and modified as appropriate.

It would be important to address each kind of value and its degree of sensitivity, as identified earlier, to determine how the planning and design strategy can respond to ensure sustainability. The approach adopted for this proposal is development-led. Sound forest planning, design and management are the goals, not limited forestry. Thus landscape enhancement is prioritised over, but does not override, a more defensive emphasis on conservation. According to this proactive approach to forestry, the results of the sensitivity assessment will not simply introduce constraints, but can more positively provide prompts for planning and design. As with all creative acts, decision makers and creators of forest landscapes need real contexts and conditions in order to educe and develop solutions.

The purpose of this integration stage of the proposed process is to assist forest planning in three ways. Firstly, it determines the acceptability of different types of forestry. If forest expansion is deemed appropriate in a given landscape, options include, for example, the purely commercial, commercial and visual amenity, or amenity and/or ecological conservation. Secondly, it can be used to determine appropriate design details (Table 1) and species, silviculture and management practices such as harvesting, thinning, brash deposition and forest road design (Table 2). Given the main focus of this paper on forest landscape aesthetics, the management constraints proposed reflecting different sensitivity levels are aimed at minimising adverse landscape aesthetic impact. Further constraints can be added later, based upon due consideration of each sensitivity class, to address the other areas of concern. The third function is to provide a structure for the content and level of detail required by both forestry and planning authorities, when submitting for approval and grant aid (Table 3).

The contents of Tables 1 and 2 are intended as examples of the possible implications of sensitivity. Rather than proposed standards degenerating into rigid prescription, they should be implemented simply for reference without legal or regulatory enforcement, thus providing useful assistance to all concerned bodies. It should be noted that the suggested administrative requirements in Table 3 could be further developed to provide the basis for a self-assessment process in relation to landscape impact. Different levels of detail should be required in formal submissions, corresponding to the differences in sensitivity. Accordingly, more information, in the form of both graphic simulations and written assessments and specifications, might be required for a site in a landscape of high sensitivity. Such a process could obviate the need to prepare a complete environmental impact statement where the assessment of other impacts might not be critical. It would ensure that the landscape impact of each proposal would be assessed according to the sensitivity class concerned.

The final outcome of the model would be a clear indication of desired afforested landscapes at a regional or county scale in the form of a forestry strategy. The resulting document would parallel and complement a conventional county development plan. It would not be prescriptive, but rather would serve for consultation, providing a starting point for ultimate compromise by all parties concerned.

Table 1. *Forest planning and design alternatives in response to landscape character and sensitivity.*

Planning Relationship to macro context		*Limited cover* ◄——► *Extensive cover*
Extent	*Scale*	% Cover expressed as a percentage of landscape character area %
Character integrity	*Size*	Small (confined) Small-medium Medium-large Large (extensive)
Disposition	*Arrangement*	Occasional Scattered / frequent Continuous
Character articulation	*Location*	Focus forests in certain parts of the landscape
Design Relationship to immediate context		*Human-influenced* ◄——► *Naturalistic*
Configuration	*Shape*	Rectangular Rectangular-curvilinear Curvilinear Interlocking
Spatial structure	*Pattern*	Uniform Occasional clearings Frequent clearings Parkland
including silviculture	*Proportion*	Not corresponding to context Corresponding to context
	Edge	Solid / dense Open Diffuse
Composition	*Margin*	Coniferous Broadleaf Mixed Scrub included
Species structure	*Colour*	Homogenous Peppered Mottled drifts Deciduous species included
	Texture	Dense Fine variation Coarse variation (drifts) Graduated drifts

Table 2. *Forest management practices in response to landscape character and sensitivity.*

Management Practice Relationship to immediate context		*Evident* ◄——► *Inevident*
Shape and Edge	*Roads*	Straight Curvilinear Curvilinear and diffuse
	Rides	
	Fire breaks	
Surface	*Thinning*	Regular lines Irregular lines and single trees Single tree selection
	Brash	Scattered Windrows Burnt / chipped Removed
	Boulders	Visible Not visible
	Boundary zone	Distinct Indistinct

Table 3. *Suggested administrative requirements for sensitivity classes.*

	Class I	Class II	Class III	Class IV	Class V
Description	Low sensitivity	Moderate sensitivity	High sensitivity	Special landscape	Unique landscape
Objectives	Commercial	Commercial	Commercial / visual amenity	Amenity Ecology Culture Social interconnection	As existing
Professional involvement	Forester with some training in landscape principles	Forester adequately trained in landscape principles	Forester adequately trained plus landscape expert	Forester plus ecologist / amenity expert	Not relevant
Graphic submission to Forest Service*	As per current standards with maps at min. 1:10,560	Maps at min. 1:10,560 and specific details for special locations at 1:2,500 as well as photographic overlay visual simulations from min. two VRPs† depicting phases in rotation	Maps and plans detailed at 1:10,560 - 1:2,500 and photorealistic visual simulations from all VRPs depicting phases in rotation	Maps / plans and sections detailed at 1:10,560 - 1:500 depicting ecological / amenity management plan	Not relevant
Specification submitted to Forest Service*	List species and outline silvicultural & management systems proposed	Detailed description of species, silvicultural & management systems proposed	Detailed description of species, silvicultural & management systems proposed. Consideration of windthrow to be evident	Detailed ecological / amenity management plan	Not relevant
Aesthetic assessment and justification submitted to Forest Service*	Not necessary	Outline landscape architectural assessment of and response to both site and context concerning all rotation phases	Detailed landscape architectural assessment of and response to site and context concerning all rotation phases	Not necessary	Not relevant

**Note:* Under existing legislation, a forestry proposal would be reviewed by both the Forest Service and the relevant Local Authority under the following circumstances:

(a) If the proposal is greater than 25 ha (if development is greater than 70 ha, an environmental impact assessment would also be required).

(b) If the development is located in an area deemed to be 'sensitive' by the Local Authority.

† VRP or viewshed reference point representing a key viewing area, such as a road or a golf course.

Implementation

> Our profession needs a proactive, environmentally responsible, economically reasonable approach to regulatory proposals... Foresters must take the lead in regulation if they are to be land managers and stewards, not just technicians controlled by other citizens, professions and politicians.
>
> (Cubbage, 1991)

A fundamental question regarding the achievement of sound forestry is the degree to which legislation should be introduced and strict controls imposed. In considering the effectiveness of legislation for the USA, Cubbage (1991) points out that it can range from being "a toothless model law" likely to be ignored, to a rigorous model likely to restrict the necessary freedom for adaptation to individual conditions. Against a background where different environmental groups have successfully brought numerous lawsuits against the USDA Forest Service, environmental protection agencies and private landowners, the same author advocates formalised co-operation and consensus rather than regulation. Furthermore, he advocates a careful public relations effort, the concerted education of all foresters and land managers, and the implementation of the concept of best management practices.

In Ireland to date, considerable freedom exists for landowners regarding the extent, configuration and composition of their forests. Control by the Forest Service, as the governing body, is exercised through grant aid, but also through guidelines, licences and incentives. These together provide a controlling mechanism which is seen as preferable to one of rigid demands and imperatives. Certainly, the possibility of introducing a legislative mechanism for the implementation of forest planning control and design guidelines cannot be undertaken lightly. But some regulation, including that backed by law, is necessary.

As is evident from the contents of this paper, planning and design of forestry involves the identification and subsequent reconciliation of a complexity of factors. One way of achieving this is by interaction of the relevant expertise in an attempt to achieve optimisation of forest landscape enhancement, as well as adaptation to specific circumstances. The GIS-based FIPS will provide a medium for the realisation of this interaction.

Conclusion

The urgent need to develop ways in which appropriate standards for forestry in the landscape can be established, whether through planning, design, management or operations, is clearly evident, given the current climate of 'bottom-up' public pressure and 'top-down' pressure on local authorities by government departments. The development and implementation of forest landscape planning and design tools will have positive consequences for much of the Irish countryside, particularly in scenic areas. It will also have consequences for forest productivity. For example, design and management constraints might entail a certain amount of loss in forest cover or management efficiency at the site level. At the broader landscape scale, however, the greater acceptability of forestry by the public, arising from landscape enhancement and improved recreational opportunities, will result in a net gain in the form of increased forest cover. Care must be taken, however, to avoid encumbering the whole process, due to onerous statutory procedures in applications for approval or even appeals.

Some of these procedures could be obviated by providing a common reference for all concerned, comprising forestry capability zones, a comprehensive set of guidelines covering forestry in a representative selection of landscape types, and categories of requirements in relation to values and their sensitivity. These would add to existing forestry control mechanisms such as the various grant schemes, tree felling licences and environmental impact assessment requirements, and would thus contribute substantially towards the establishment and achievement of overall forestry standards. The entire process, as depicted in the proposed model, could draw together foresters, planners, landscape architects and administrators, as well as other expert and interested parties. The process could thus provide the basis for consultation, involving conciliation and compromise. Flexibility in both interpretation and application of landscape objectives at the site-specific level would be inherent to this process. Accordingly, the use of common reference material such as guidelines and sensitivity classes must be one of indicative performance, not rigid prescription.

At this point in the development of forestry in Ireland, the opportunity exists to achieve an overall synthesis of policies, structures and measures to ensure that a balance is achieved among the issues facing forestry. As far as landscape is concerned, forests need not be a problem, but rather can act as a major force in landscape enhancement and as a medium for the aesthetic experience of nature. It is very important to rise to the challenge by developing forestry in Ireland in a way which is decisively proactive. While referring specifically to USA, the following quotation captures something of the complexity of this challenge:

> We need at this moment, as much as any country ever needed, the development which makes clear the influence of nature upon intellectual and spiritual life; an integration that involves science, the arts, and human interest in order to give clear expression to what is most significant in our relation to nature.
>
> (Smith, 1936)

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General paper

Tree collections in Ireland

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Summary
In contrast to the 33 species which occur naturally, several hundred exotic or introduced species are represented in Ireland. From the 1600s, tree species from the temperate regions of the world have been cultivated in Irish parks and demesnes. In the 18th and 19th century, plant collections were established by private owners who were keen to plant recently introduced species. In this century, tree collections were established by private individuals, the State and by local authorities. Trees were planted in arboreta, such as the John F. Kennedy Arboretum, Co. Wexford, or in informal Robinsonian style gardens, such as Mount Usher Gardens in Co. Wicklow. Some 35 collections are extant on this island. Collections such as those at Powerscourt, Co. Wicklow, Birr Castle, Co. Offaly, and Castlewellan in Co. Down, are of international repute. While the tree collections are important tourist destinations, attracting some 700,000 visitors annually, they also represent a resource for the nursery industry and for genetic and taxonomic studies, and are an integral part of garden design.

Tree collections
The number of tree species which occur naturally in Ireland is limited. Species of birch (*Betula* spp.) and oak (*Quercus* spp.), together with common yew (*Taxus baccata* L.), are among the 33 species described in *Trees of Ireland – Native and Naturalized* (Nelson and Walsh, 1993). In contrast, several hundred exotic or introduced species are represented. From the 1600s to recent times, trees have been acquired from overseas and grown alongside native trees in Irish gardens, parks and demesnes. A collection is taken to be a representative number of trees from a particular genus, group of genera (such as the conifers) or regions of the world. Areas of parks and estates where trees only are cultivated are known as arboreta (trees, in general) and pineta (conifers, in particular). In most situations in Ireland, trees are cultivated in association with shrubs and herbaceous plants, or in some situations, with native wild flowers. Many of the older collections were established by private collectors, and many of these are now under State ownership. Other collections were established by the State and in recent years, by local authorities in collaboration with the Tree Council of Ireland and the general public. This paper examines the evolution of tree collections in Ireland and describes a representative number of these.

The 18th century
One of the earliest plant collectors in Ireland was Sir Arthur Rawdon of Moira, Co. Down. In the late 17th century, he sent his head gardener, James Harlow, to Jamaica to collect plants (Nelson, 1984), which were later grown successfully in a prototype greenhouse. Another tree enthusiast, Lord Clanbrassil, is remembered in the nomenclature of *Picea abies* 'Clanbrassiliana', a dwarf form of Norway spruce. There is a fine specimen of this cultivar in his garden at Tollymore, Co. Down, now a forest park.

Records of the plant collections of Rosannagh, Rathnew, Co. Wicklow, held in the archives of the National Botanic Gardens, Glasnevin, Dublin, detail planting undertaken by the Tighe family between 1718 and 1874. They indicate the range of European and Middle Eastern trees in cultivation in Ireland at that time, including horse chestnut (*Aesculus hippocastanum* L.), beech (*Fagus sylvatica* L.), Cedar of Lebanon (*Cedrus libani* A. Richard), evergreen oak (*Q. ilex* L.), common laburnum (*Laburnum anagyroides* Med.), common lime (*Tilia* x *europaea* L.), common walnut (*Juglans regia* L.) and Spanish chestnut (*Castanea sativa* Mill.). One of the earliest introductions from eastern North America was the tulip tree (*Liriodendron tulipifera* L.). There are several old specimens in existence, including a fine example at the K Club, Straffan, Co. Kildare.

John Foster (1740-1828), who is perhaps better known as the last Speaker of the Irish House of Commons, was also an important plant collector. He had 1,700 different trees and shrubs in his estate at Collon, Co. Louth, and was one of the first to plant copper beech (*F. sylvatica* 'Purpurea') in Ireland. Foster was also instrumental in the establishment in 1796 of the Botanic Gardens (now the National Botanic Gardens) in Glasnevin by the Dublin Society (now the Royal Dublin Society) (Nelson and McCracken, 1987). Some very old but extant specimens of Cedar of Lebanon and common yew predate the establishment of the gardens. Today, the gardens maintain important collections of trees, including oak, maple (*Acer* spp.), birch, poplar (*Populus* spp.) and chestnut. The specimen of Caucasian elm (*Zelkova carpinifolia* (Pall.) K. L. Koch), a relative of the elm (*Ulmus* spp.), is one of the finest in cultivation. The often-photographed weeping atlas cedars (*C. atlantica* 'Glauca Pendula' and 'Glauca') are a familiar image of the Gardens.

Fine examples of the Irish yew (*T. baccata* 'Fastigiata') are grown not only in the National Botanic Gardens, but in many collections throughout the island. The Irish yew was discovered between 1740-60 in the Cuilcagh Mountains. A plant was brought to Florencecourt, Co. Fermanagh, from where it was propagated. It is now in widespread cultivation in Ireland and throughout the temperate world, as an architectural specimen tree in gardens and parks.

John Claudius Loudon describes 18 Irish estates and their trees in Arboretum et Fruticetum Britannicum (Loudon, 1838). Several of these estates, including Antrim Castle, Co. Antrim, Castle Ward, Co. Down, Kilruddery, Co. Wicklow, and Castletown in Co. Kildare, are managed as important historic landscapes which are open to the public.

The 19th century

In the early 19th century, plant collectors such as David Douglas, Archibald Menzies and William Lobb, were sent by horticultural societies and nurseries in Britain to the western United States and South America to collect plants. The subsequent introduction of new trees prompted the establishment of arboreta in parks in Britain and Ireland.

From the 1840s, Lord Barrymore purchased trees from London nursery firms for his estate at Fota in Co. Cork. A catalogue of his collection published in 1912 listed fir (*Abies* spp.), spruce, Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), hemlock (*Tsuga* spp.), pine (*Pinus* spp.), coast redwood (*Sequoia sempervirens* (D. Don) End.) and giant sequoia (*Sequoiadendron giganteum* (Lindl.) Buchholz). A specimen of date palm (*Phoenix canariensis* Hort. et Chabaud.) planted in 1894, is the only known example of this species in outdoor cultivation in Ireland. Of particular conservation importance is Bermuda cedar (*Juniperus bermudiana* L.), a relative of the native common juniper (*J. communis* L.), which was planted in 1916 and is listed as vulnerable in the wild in the *IUCN Red Data Book* (Anon., 1978).

In the 1780s, the monkey puzzle or Chile pine (*Araucaria araucana* (Molina) K. Koch) was introduced into cultivation from Chile by Archibald Menzies. From the 1840s, it became a popular garden tree and was often planted as a specimen on lawns. Avenues of monkey puzzle were less common, with fine examples remaining at Powerscourt, Co. Wicklow, and Woodstock, Inistioge, Co. Kilkenny. A line of giant redwood, planted in the 1860s and now between 30-35 m tall, adorn the formal Italianate garden at Powerscourt. Giant redwoods are easily identified by their soft cork-like bark and massive size. In an area known as Tower Valley, Lord Powerscourt planted a comprehensive collection of North American conifers, many of which are notable specimens of their type in Ireland. A massive specimen of Monterey cypress (*Cupressus macrocarpa* Hartw.), planted in 1898 by Lord Powerscourt, measured 34 m in height in 1980.

Whereas Lord Powerscourt laid out a formal garden on a large scale and grew conifers in a formal manner as well as informally in a pinetum, the Ball Acton family at Kilmacurragh, Co. Wicklow, planted a Robinsonian style garden, where exotic trees were interspersed among native trees in a naturalistic manner. Kashmir cypress (*C. cashmeriana* Royle ex Carr.), a cypress native to India distinguished by its glaucous blue foliage and elegant habit, is uncommon in Irish gardens. Rhododendrons (*Rhododendron* spp.) have attained tree-like proportions in the garden. An avenue lined with a red-flowered hybrid, *Rhododendron* 'Cynthia', is a spectacular sight each spring. While *Cryptomeria japonica* 'Elegans', a cultivar of Japanese red cedar, is common in Irish gardens and often recommended as a dwarf conifer, the massive widespreading specimen at Kilmacurragh gives lie to any such suggestion.

The landscape design at Abbeyleix is typical of many 19th century demesnes, with formal terraces south of the house, surrounding areas of parkland with specimen trees, and a pinetum located some distance from the house. There are also remnants of the ancient oak forest, with one specimen reputed to be 1,000 years old. While Spanish chestnut occurs frequently in Irish collections, *Castanea henryi* (Skan.) Rehd., a specimen of which is found at Abbeyleix, is very uncommon.

The tree collection in the walled garden at Castlewellan, Co. Down, now the National Arboretum in Northern Ireland, was developed from the 1850s by Lord Annesley. Situated in a walled garden on a south-facing site, many trees have attained a large size and are notable specimens of their type. *Juniperus recurva* 'Castlewellan', a cultivar of drooping juniper, is an example of a plant from a garden which has long since entered the trade.

Avondale in Co. Wicklow, the home of Charles Stewart Parnell, was originally planted by Samuel Hayes in the 1700s. In the early 20th century, a forest garden including conifers and eucalypts (*Eucalyptus* spp.) was planted by A.C. Forbes. Forestry plots planted on either side of a broad ride frame splendid views to the surrounding mountains.

Mount Usher in Co. Wicklow was acquired by the Walpole family in the 1860s and developed as a Robinsonian garden from the 1890s. Detailed planting records have been maintained, noting the introduction into the garden of plants from Irish gardens and nurseries and from other countries. Augustine Henry identified a specimen of the eucalypt, *E. johnstonii* Maiden, planted in 1911 from seed obtained from the Sydney Botanic Gardens. A specimen of *Emmenopterys henryi* Oliver is the sole record of this tree in Irish gardens. An example of Montezuma pine (*P. montezumae* Lamb.), a Mexican 5-needled pine, was planted by Lord Powerscourt in 1909 and is now approximately 34 m tall. Two 'pups' or seedlings of this tree grow by the Suspension Bridge over the River Vartry. The garden is mentioned, along with many others, in *Trees of Great Britain and Ireland* by Elwes and Henry (1906), which gives an account of trees occurring naturally in these islands and those growing in parks and arboreta in the early years of this century.

Certain trees become collector items and are much sought after by garden owners and plant enthusiasts alike. The handkerchief tree or dove tree (*Davidia involucrata* Baill.) is one such example. It was discovered in 1869 by the French collector Abbé Armand David, seen by Augustine Henry but introduced into cultivation by E.H. Wilson in 1903. Wilson described it as "the most interesting and most beautiful of all trees of the north temperate flora", with its white petal-like bracts likened to "huge butterflies hovering among the trees".

The 20th century

Conifers make an important contribution to Irish arboreta, with some 230 species from 45 genera and eight families represented in collections. Perhaps one of the most unusual is the Chinese deciduous cypress (*Glyptostrobus lineatus* (Poir.) Druce), a deciduous species related to the swamp cypress (*Taxodium distichum* (L.) Richards).

Conifers form an important part of the collection of trees at Birr Castle in Co. Offaly. From the 1930s, the 6th Earl of Rosse gathered a comprehensive collection of trees and shrubs and planted them within an existing parkland landscape. Fine specimens of Mexican cypress (*C. lusitanica* Mill.), Monterey cypress and Nootka cypress (*Chamaecyparis nootkatensis* (D. Don) Spach) are planted on the banks of the River Camcor. Nearby, a specimen of *Carrierea calycina* Franch., a species from China related to the genus *Azara* with white flowers hidden in the evergreen leaves, is a rare find in cultivation. Other interesting trees at Birr include the rare walnut, *J. cathayensis* Dode, and species of hickory (*Carya* spp.). Poplars are often associated with northern France where they can be found lining riverbanks. At Birr, specimens of grey poplar (*P. canescens* (Ait.) Sm.) and the Chinese necklace poplar (*P. lasiocarpa* Oliv.) have attained large sizes. Some plants are grown from seed imported from the wild. One such example at Birr is the unusual lime, *T. henryana* Szyszyl., planted from seed supplied by the Chinese Lushan Botanic Garden in 1938.

The name Henry occurs frequently in relation to Irish arboreta. Augustine Henry (1857-1930) trained as a medical doctor (Pim, 1984). While in China from 1881-1900, Henry collected many plant specimens which he sent to the Royal Botanic Gardens, Kew. He then studied forestry in France and held an appointment in Cambridge before becoming the first Professor of Forestry in the Royal College of Science (now University College Dublin) in 1913.

In the 19th century, botanic gardens and nurseries sent plant collectors to collect seed in the wild. In the period between the two world wars, syndicates of garden owners sponsored plant collectors such as George Forrest and Frank Kingdon Ward to collect seed in China and elsewhere. One such sponsor in this country was Lord Headfort at Headfort, Kells, Co. Meath. Stands of Delavay's silver fir (*A. delavayi* Franch.) and many rhododendrons were cultivated from Chinese seed.

In 1932, H.M. FitzPatrick listed the principal trees in 85 collections in Ireland. FitzPatrick's work, *The Trees of Ireland – Native and Introduced* (1932), was to remain a standard reference for many years.

The establishment of tree collections continued after the second world war. From 1946 onwards, the late Roderic More O'Ferrall developed an important collection of medium sized trees at Kildangan, Co. Kildare, which include ornamental specimens of cherry (*Prunus* spp.), apple (*Malus* spp.), rowan (*Sorbus* spp.) and birch. There is also a notable specimen of *Dipteronia sinensis* Oliver, a relative of sycamore (*A. pseudoplatanus* L.).

While Malahide Castle dates from 1185 and a strong gardening tradition long associated with the Talbot de Malahide family, the current gardens were not developed until 1948, when Milo Lord Talbot de Malahide succeeded to the property. Australian and New Zealand plants in particular are represented in the collection, including eucalypts, daisy bushes (*Olearia* spp.) and *Pittosporum* spp. The specimens of paper bark maple (*A. griseum* (Franch.) Pax) and the mahogany-like barked Tibetan cherry (*P. serrula* Franch.) are among the finest in the country.

While most of the trees in cultivation were introduced prior to the second world war, one exception which has become popular as a garden and park tree is dawn redwood (*Metasequoia glyptostroboides* Hu et Cheng), a conifer originally known only from fossil records but found in the wild in China in 1941. Seed was introduced to the Arnold Arboretum in Boston and distributed to gardens around the world. Specimens from this early distribution of seed occur in the National Botanic Gardens, Glasnevin, and at Mount Usher in Co. Wicklow.

Recent arboreta

The John F. Kennedy Arboretum in Co. Wexford was opened in 1968 and is managed by Dúchas – The Heritage Service. It includes 125 ha devoted to trees and shrubs, and a further 60 ha of forestry plots. The arboretum, which contains over 4,500 different types of trees and shrubs, is the most comprehensive collection on this island. Also in the south-east, the gardens at Mount Congreve, Co. Waterford, developed by Ambrose Congreve, maintain an important collection of trees and shrubs of both botanical and horticultural importance. Both collections could serve as important sources of propagation material for the nursery trade.

The most recent inventory of woody genera in Irish gardens was undertaken by the author on behalf of An Taisce between 1979-83 (Forrest, 1985). Twenty private collections were catalogued. The results were then amalgamated with records from publicly-owned collections, creating an inventory of 17,500 records representing approximately 7,000 taxa of trees and shrubs.

Since then, two more tree collections have been established, both of which were joint ventures between the Tree Council of Ireland and a local authority, with sponsorship from various groups and private individuals. The Millenium Arboretum at St. Anne's Park, Clontarf, Dublin, was established in 1988 by Dublin Corporation and the Tree Council to mark 1,000 years of Dublin City. The arboretum incorporates over 1,000 different types of trees from all over the world but commonly seen in small private gardens and public open spaces. In the late 1990s, the shape and form of the arboretum are clearly evident, as the trees grow and develop. In February 1996, the first tree in the Famine Commemorative Arboretum was planted. Situated at the Corkagh Park, Clondalkin, Dublin, the arboretum will include 150 different species of trees from around the globe to mark the emigration of Irish people to many countries worldwide. The Famine Commemorative Arboretum is a joint venture between South Dublin County Council and the Tree Council.

Conclusion

On this island located between the latitudes 52-55°N, we have garnered trees from North and South America, the Antipodes, the Orient, the Himalayas and Europe. Two main factors have contributed to the development of the approximately 35 tree collections throughout this island: our mild temperate climate and the tireless efforts of garden owners and their staff who were, and continue to be, imbued with the spirit of trees.

The tree collections have served and continue to serve many functions. There are many examples of trees which have gone into commerce from Irish collections, and these continue to act as a source of new examples of cultivars for the nursery trade. They represent an important genetic resource in the conservation of rare species, and a source of material for taxonomic study. The tree collections represent an integral part of the gardens within which they are located, and therefore contribute to the tourist attraction these represent. Almost 700,000 visits are made to Irish gardens each year. They also represent a source of enjoyment and pleasure, and of inspiration to artists.

Some collections are no more, others are senescent, and a few are in their juvenile phase and are set to mature at some point well into the next century. Ireland's tree collections are a testament to those who first collected the trees, the owners and gardeners who cultivated them on their land, those who had the foresight to undertake State-funded arboreta, and present day managers of parks, estates and forests.

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General paper

The potential of western red cedar (*Thuja plicata* D. Don) in Ireland

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Summary
Western red cedar (*Thuja plicata* D. Don) is a species with enormous potential in Ireland. It is highly suited to the island's mild wet climate and the heavy wet soils currently available for forestry development. The species is capable of high growth rates and productivity, and is noted for its high quality timber which possesses several unique wood properties. It is a shade tolerant species suitable for underplanting and for use in mixtures with other conifers, notably Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and also as a nurse species in broadleaf plantations. While its growth rate does not compete with Sitka spruce on poorer site types, especially at higher elevations, western red cedar is capable of producing a high yield class crop on lower, more sheltered drumlin soils and on better quality lowland soils. While more detailed research is required, the favourable characteristics of western red cedar prompt its inclusion as a major species in future planting programmes, particularly in light of the current emphasis on diversification in Irish forestry.

Introduction
The Irish forest industry has become highly dependent on Sitka spruce (*Picea sitchensis* (Bong.) Carr.). The optimum management techniques required for growing this species are now well established. Over recent years, increased emphasis has been given to diversification and its role in maintaining ecological diversity and sustainability, and developing new markets. In light of this move towards diversification, as set out in the Government's strategic plan for forestry in Ireland (Anon., 1996), alternative fast growing conifer species need to be considered. It is within this context that this review was undertaken to study the potential of western red cedar (*Thuja plicata* D. Don) in Ireland.

Natural habitat
Western red cedar is a major species of the Pacific Northwest coast of America. Its range stretches from the coastal regions of southern Alaska (57°N) through the coastal regions of British Columbia, western Washington and Oregon to northern California. It extends inland as far as Idaho and Montana (Anon., 1965; Savill, 1991). It grows from sea level to an elevation of 1,500 m in coastal regions in Oregon, and is found between 600-2,100 m in the Rocky Mountains (Minore, 1990).

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Under favourable growing conditions, western red cedar can attain large proportions of 2.4 m in diameter and 60.0 m in height. The current record holding specimen measures 5.8 m in diameter and 54.3 m in height, and stands in "grotesque isolation, inland from Hoh River, Olympic Peninsula, Washington" (Kirk and Franklin, 1992). In its native rainforests, western red cedar can live up to 1,000 years, partly due to its tendency to produce an exceptionally broad base which resists toppling by wind.

Western red cedar is confined almost entirely to regions having high precipitation and atmospheric humidity (Sudworth, 1918, cited in Anon., 1965). In Puget Sound, Washington, the cool summers, mild winters and abundant rainfall create the most favourable growing conditions. In the area, annual precipitation rates range from 1,250-1,500 mm, reaching as high as 2,500 mm on higher ground (Anon., 1965).

In inland regions of the natural range, the climate is characterised by a short summer season with minimal precipitation. Thirty-five percent of the total annual precipitation of 750-1,200 mm falls as snow. Average annual temperatures range from 4.4-10.0°C. Western red cedar can withstand very low winter temperatures and is fairly resistant to late spring frosts (Savill, 1991).

Western red cedar is often found scattered among other conifers in moister parts of mixed forests, occasionally constituting up to 50% of the stand (Harlow *et al.*, 1996). It is occasionally found in pure stands, usually in low spots where the roots of other conifers would be unable to survive, or in disease-infected soils. The principal associated species in coastal areas are Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Sitka spruce, nootka cypress (*Chamecyparis nootkatensis* (D. Don) Spach), firs (*Abies* spp.) and mountain hemlock (*T. mertensiana* (Bong.) Carr). It also grows with an assortment of broadleaf species, including red alder (*Alnus rubra* Bong.), Oregon maple (*Acer macrophyllum* Pursh) and western balsam poplar (*Populus trichocarpa* Hook.), especially in very wet areas in coastal regions. In the northern Rocky Mountains, common associates include western white pine (*Pinus monticola* Dougl. ex D. Don), western larch (*Larix occidentalis* Nutt.), lodgepole pine (*P. contorta* Dougl.), grand fir (*A. grandis* Lindl.), Engelmann spruce (*P. engelmannii* (Parry) Engelm.) and alpine fir (*A. lasiocarpa* (Hook.) Nutt.) (Anon., 1965).

History

Western red cedar was introduced into Britain in 1853, when John Veitch, an Exeter nurseryman, sent his colleague William Lobb to collect seed of the many rare and remarkable conifers reported to exist in Oregon and British Columbia (Anon., 1957). This late introduction is somewhat surprising, as western red cedar was first observed by the Malaspina expedition on the west side of Vancouver Island, British Columbia, in 1791 (Anon., 1957; Harlow *et al.*, 1996). A specimen was sent back to the botanist David Don who described it as early as 1794.

Probably the first occasion the species was used in forestry in Britain was at Benmore, Argyll, in 1876-77 (McBeath, 1914, cited in Anon., 1957). Until 1919, it had a limited use as a forest tree, being planted in small plots or as an edge tree to plantations of other species (Anon., 1957).

Inventory

After its purchase by the newly-formed Department of Agriculture in 1903, a series of stand plots was established in Avondale Estate, Co. Wicklow, to test the suitability of a range of species for commercial planting in Ireland. An assessment of the suitability of some of the rarer species to Irish soil and climatic conditions was also intended. While many species failed, others, including western red cedar, proved promising. One acre of the species was planted in 1906 in a mixture, with 75% European larch (*L. decidua* Mill.) included as a nurse species. This high quality stand, which attained a yield class of 24, is regarded as a prime example of the potential of western red cedar in Ireland. Some of the older estates acquired by the Forestry Division, such as Vandeleur Estate, Co. Clare, and Rostrevor Forest, Co. Down, were also planted with western red cedar.

According to Coillte's 1995 inventory, 119.4 ha of western red cedar are under State ownership, with an average yield class of 18 m^3/ha/yr. Figure 1 shows the area of western red cedar planted each decade since its first planting in the 1850s. The largest cedar plantations are found in Hollyford, Co. Limerick, Swanlinbar in Co. Cavan, and Avonmore, Co. Wicklow. Coillte policy states its intention to plant at least 200 ha per annum from 1993 onwards, on fertile, low elevation, sheltered sites (Anon., 1990). The last inventory of private woodlands in 1973 estimated that 40.2 ha (11,910 m^3) of western red cedar were under private ownership, with a mean yield class of 15 m^3/ha/yr.

Western red cedar was the most widely used of all the minor conifer species planted in the UK (Aldhous and Low, 1974). Since 1950, over 5,000 ha of plantations have been established.

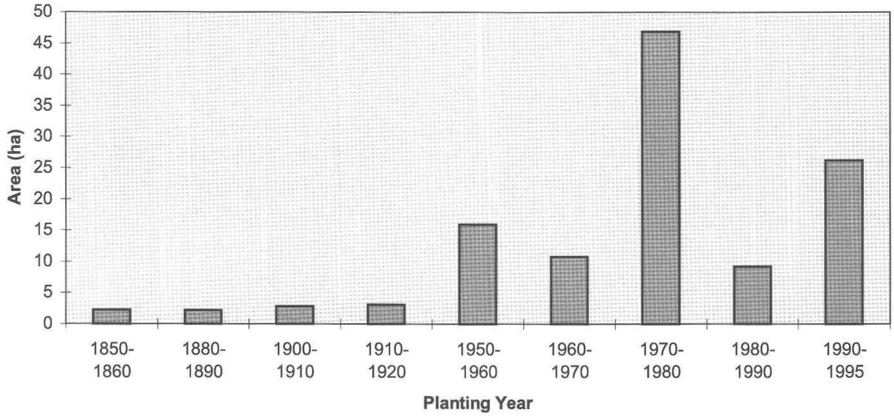

Figure 1. *Total area of western red cedar planted per decade since 1850 on State property in Ireland.*

Silvicultural characteristics

The most important silvicultural characteristic of western red cedar is its shade tolerance, with the species performing relatively better at lower light levels than Douglas fir and western hemlock (Carter and Klinka, 1992). Its low spatial crown requirements and shade tolerance contribute to high timber yields. Western red cedar is particularly suitable for use in mixtures with broadleaf species, as its narrow crown does not interfere with neighbouring trees (Savill, 1991). The late Ray Bourne devised a planting system comprising a larch matrix, into which groups of five broadleaves (e.g. oak (*Quercus* spp.)) are planted in a diamond pattern, with four strong shade bearers, such as western red cedar, planted at the corners (Garfitt, 1995).

Western red cedar is useful for underplanting and was frequently planted under old oak coppice and European larch (Hiley, 1954). The species can play an important role in continuous cover forestry systems, as demonstrated by the high quality stems growing in the Bradford-Hutt plan (Timmis, 1994).

Van der Kamp (1988) describes western red cedar as being "remarkably free of serious diseases or insects". Formerly, it was a difficult species to propagate, due to the occurrence of *Didymascella thujina* in nurseries. This disease, however, can now be treated with fungicides (Savill, 1991). The species appears to be more susceptible than most conifers to *Heterobasidion annosum* and *Armillaria* spp.

Western red cedar is found on a range of site conditions, from slightly dry to wet, nutrient poor to nutrient rich, and acid to slightly alkaline (Anon., 1965). The species is favoured in ravines, gullies, flood plains, along river banks, swamps and bogs (Lavender *et al.*, 1990). It is seldom found on dry soils, although stunted growth is occasionally found on such sites (Harlow *et al.*, 1996).

Available data from the UK (Aldhous and Low, 1974) show western red cedar to be at its best on lowland sites, growing better than Sitka spruce and having a greater advantage over other species on imperfectly drained soils. Sitka spruce performed better above 275 m in England and Wales, and above 150 m in Scotland. Western red cedar grew faster than Douglas fir on most sites, and became increasingly more productive than Douglas fir on higher yielding sites. On the chalk downlands in the south of England, most conifers have been notably unsuccessful, many having been afflicted with lime-induced chlorosis after promising early growth (Wood and Nimmo, 1962). Western red cedar remains one of the few conifer species usable on such sites.

The species seems to be most productive on heavier lowland soils, especially gley soils and those with a slightly alkaline nature. Hence, it would be the ideal choice for afforestation along the drumlin belt in Counties Cavan, Monaghan and Limerick. The presence of western red cedar on the muskegs of North America led to attempts in Ireland and the UK to establish it on peat bog (Anon., 1957). These attempts were generally unsuccessful in comparison to Sitka spruce and lodgepole pine, although not on all peatlands. In the species trial at Trench 14, Clonsast Bog, Co. Offaly, western red cedar was the fourth most productive conifer, with a top height of 7.9 m and a yield class of 16 recorded at year 18 (Carey and Barry, 1975).

There have been relatively few published studies on the nutrition and fertilisation of western red cedar. It is said to be not as nutrient-demanding as its companion species Douglas fir, western hemlock and notably, Sitka spruce (Kimmins, 1987). The species is associated with ground vegetation indicating high nitrate availability, although it does occur on coastal salal (*Gaultheria shallon* Pursh.) dominated sites which are deficient in nitrogen and phosphorus. On northern Vancouver Island, British Columbia, the dominant forest type is old-growth cedar-hemlock. When these forests are harvested, the new plantations grow well initially, but enter check by year 6-8 due to low nitrogen and phosphorus availability, and competition from an ericaceous shrub salal (Prescott and Weetman, 1994). Sitka spruce and western hemlock experience severe growth check, whereas cedar appears to be less influenced by the nutritional problems, and is the dominant species being used in regeneration programmes on the island. Fertilisation with 200 kg N/ha and 50 kg P/ha or organic wastes is the most effective procedure for alleviating the problem (Prescott and Weetman, 1994). Western red cedar is not as responsive to fertilisation as

Sitka spruce or western hemlock on these sites. The above phenomenon is similar to the growth check experienced on *Calluna* heathlands and peatlands in Ireland and Britain.

In 1974, an experiment was established on the nutrient-deficient old red sandstone soils in Ballyhoura, Co. Cork (Horgan, pers. comm., 1997). These soils are very impoverished, being deficient in both nitrogen and phosphorus. In the past, the stripping of the top layer of peat by locals (a practice known as 'scrawing') removed the organic matter from the site. The soils have additional problems such as indurated layers and iron pans. A species trial involving seven different conifers (Douglas fir, grand fir, Leyland cypress (X *Cupressocyparis leylandii* (Jacks. & Dallim.)), noble fir (*A. procera* Rehd.), Sitka spruce, western hemlock and western red cedar) was initiated as part of the experiment. The trial received an application of phosphorus at planting and a second application at year 12. At year 19, many of the species had stunted growth and displayed serious signs of chlorosis. Western red cedar, however, showed the best height increment and the healthiest foliage, perhaps prompting its consideration for use on some of the poorer, nutrient deficient soils in Ireland.

Soils under individual western red cedar trees exhibit a higher pH than soils under hemlock trees in the same stands, a condition associated with the high calcium content of cedar foliage (Tarrant *et al.*, 1951). The high levels of calcium in its foliage and litter, relative to other conifer species, may be attributed to the ability of western red cedar to accumulate calcium in excess of its nutrient requirements and to therefore act as a 'calcium pump' to the site. The requirement for calcium is unclear and complex. Imper and Zobel (1983) found that, in southwest Oregon, the distribution of the species was related to the soil Ca:Mg ratio. For optimum growth, Krajina *et al.* (1982) describes western red cedar as requiring a nutrient-rich soil, with a well-balanced supply of both calcium and magnesium, and nitrogen present in the form of nitrate.

The magnitude of nutrient uptake and the relative importance of the different nutrients vary considerably between species. Broadleaves tend to have the greatest overall uptake, with calcium being the dominant element. Nitrogen dominates the annual uptake of most conifers, although some genera, such as *Thuja* and *Chamaecyparis*, have an uptake pattern more similar to broadleaves, requiring nutrients in the following order of preference: calcium; nitrogen; and phosphorus.

Forestry Commission research data for losses at planting show western red cedar to have one of the highest failure rates (Aldhous and Low, 1974). Survival and early growth is remarkably better under shelter than in the open. In Ireland, some foresters have noted problems when transplanting western red cedar. The reasons for this are uncertain but might be due to a number of factors such as poor quality nursery stock, poor handling and transportation, or exposure.

Growth is initially slower than Douglas fir and Sitka spruce on almost all sites (Aldhous and Low, 1974). The species is more productive than Norway spruce (*P. abies* (L.) Karst.) on lowland sites, but less so on intermediate upland sites. On the more exposed upland sites, especially in Scotland, it generally fails.

The planting of pure stands in the Pacific Northwest is not common. It is more often used in association with other species, with western red cedar being planted in wetter areas, areas of heavy brush or pockets with a history of root rot. Relatively little is known about the development of western red cedar in either pure or mixed stands. Pure even-aged stands on upland sites in western Washington can attain standing volumes comparable to pure Douglas fir by year 50. Such stand conditions also result in a narrow sapwood and very little taper or fluting. Pure stands minimise large branches and corresponding knot development. Western red cedar grows much slower and with more tapered, fluted stems in mixed stands, as it readily becomes overtopped by other species.

Other establishment problems include browsing by large animals and rodents, and drought. Protection from rabbits, deer and other animals is often essential. Due to the lack of natural predators, introduced deer stocks on the Queen Charlotte Islands have reached high population densities, resulting in serious overbrowsing. Western red cedar has been seriously depleted on the islands, and in some areas has been eliminated as regeneration in mature forests and on cutovers (Lavender *et al.*, 1990).

Western red cedar has the ability to sustain a higher density of trees than Douglas fir or western hemlock at a given top or mean height (Minore, 1983). Open stands result in larger trees, but due to slow natural pruning, artificial pruning is required to ensure quality butt logs. Most western red cedar in Ireland has been planted at the conventional 2.0 m spacing. Wider spacing combined with pruning and frequent thinning to control form and to increase individual tree growth, should be considered, with the aim of producing larger diameter material on a shorter rotation.

In Britain, dominant height growth of western red cedar is generally slower than that of other species, but early height growth to year 20 is faster than that of Sitka spruce. At years 20 and 50, the cumulative volume produced is lower than that of Douglas fir and Sitka spruce and is similar to that of western hemlock (Aldhous and Low, 1974). By year 80, however, the situation is reversed, with western red cedar having a greater cumulative volume production. Stands tend to be uniform, with a relatively small range in height and girth (Aldhous and Low, 1974). The timing of first thinning in western red cedar stands is 5-8 years later than that in Sitka spruce or Douglas fir stands of the same age and yield class. Thinnings are similar in size to those for Sitka spruce at the same height, but this height is reached 5 or more years later (Table 1).

Table 1. *A comparison of stand parameters at year 20 (yield class 14) for western red cedar (WRC), Sitka spruce (SS), Douglas fir (DF) and Norway spruce (NS). From Hamilton and Christie (1971).*

Species	*Stems/ha*	*Mid diam. (cm)*	*BA (m^2/ha)*	*Mean volume/ thinned tree (m^3)*	*Age at 20 m height*	*MAI at 20 m (YC 14)*
WRC	1,073	24	49.3	0.28	50	13.1
SS	694	24	25.7	0.30	43	13.0
DF	626	23	25.7	0.25	34	11.7
NS	722	24	33.5	0.28	46	12.3

Syleptic growth usually occurs in seedlings for the first few years and sometimes in the juvenile phase, but some species maintain this form of free growth throughout their life cycle. While growth rates may not be as high as those for proleptic species, syleptic species can capitalise on favourable conditions late in the season. Western red cedar is one such species, enabling it to take advantage of Ireland's mild climate and long growing season.

Taper in western red cedar stems results from the shade tolerance status of the species. In mixed stands, lower limbs remain alive and active beneath the shade of neighbouring trees, and continue to contribute photosynthate downwards, resulting in lower stem expansion. To avoid tapered stems, this species should be grown in even-aged, pure stands at narrow spacings or with species of similar shade tolerance. Even under these conditions, however, stems taper greatly up to 1.5 m above ground. Pruning may alleviate this problem, although some degree of buttressing may be inherent.

Fluting can occur in species with little lateral transportation of photosynthate in the phloem, a condition suggested in western red cedar by its straight grain and ease of splitting. Each limb 'supplies' the cambium directly beneath it, with the surrounding cambium fed by more vigorous limbs higher in the canopy. The suppression of an individual limb therefore results in the reduced growth and expansion of the corresponding area of the trunk. Combined with the poor lateral transport of photosynthate from adjacent areas of the stem, this gives rise to the development of an indentation or flute, which over years of growth can run from the suppressed limb down to the base of the tree. This flute will continue to deepen until the limb dies. After this point, the cambium beneath becomes reconnected to surrounding, more vigorous sources of photosynthate, and the flute is not increased. To avoid fluting, the same practices should be implemented as those for avoiding extreme taper. Fluting can also result from unusual rooting conditions, especially on excessively wet soils. In a UK study, fluting was more pronounced on hemlock, although it was also quite common in western red cedar stands (Aldhous and Low, 1974).

Forking was observed in 60% of all western red cedar plots (Aldhous and Low, 1974), becoming more prevalent with wider spacing, increasing exposure and diminishing vigour. Western red cedar is more likely to fork above breast height than at the base. Fluting and forking may be more prevalent in some seed sources (Savill, 1991). While choice of provenance may not be as important as for other Pacific Northwest conifers (Minore, 1990), origins from the north slopes of the Olympic Mountains in Washington and from Vancouver Island are recommended for planting in Britain and Ireland (Lines, 1987).

Large limbs and knots also occur where the lower limbs remain alive into the rotation. Individuals growing with their terminals in full sunlight maintain strong epinastic control, thereby maintaining a relatively conservative cone-shaped crown. If the tree becomes overtopped and is subsequently released, however, lateral branches seem to escape from the control of the terminal. Consequently, much of the increased growth is added to large branches in a spreading crown, and not to the stem wood.

Old lawn specimens of western red cedar can develop extraordinary characteristics. For example, lower limbs resting on the ground readily take root, springing up to surround the original tree with a grove of green buttresses (Johnson, 1973).

Wood properties

The sapwood of western red cedar, which is almost white in colour, is narrow, with a thickness of 2.5 cm over a wide range of diameters (Lassen and Okkonen, 1969, cited in Swan *et al.*, 1988). Thus, a high proportion of converted timber comprises heartwood, even in fairly young trees. The heartwood varies in colour when fresh, from a dark chocolate brown to a salmon pink colour to light straw. After drying, the wood assumes a uniform reddish-brown tone. After long exposure to the elements, however, this colour is lost and the wood becomes silver grey. It is straight grained, uniformly but coarsely textured and non-resinous, and has a fairly prominent growth-ring pattern. The wood also has a distinctive aroma.

Western red cedar is relatively light weight and soft. The average nominal specific gravity of old growth western red cedar is 0.31 and 0.33, based on green and oven-dried volumes respectively, and is similar to that of both Sitka and Norway spruce. The specific gravity of short rotation, second growth material does not differ much from that of old growth material (Swan *et al.*, 1988).

The average density at 15% moisture content is 390 kg/m^3, a value which is much lower than that for other common conifer species grown in Ireland. The low wood density results in low strength, but confers excellent insulating properties to the wood. The thermal conductivity of western red cedar (0.73 at 12% moisture content) is one of the lowest for a commercially important species. A cross section 25 mm in thickness is equal in insulating effectiveness to 180 mm of brickwork or 300 mm of concrete.

Western red cedar timber splits easily. This property, combined with a straightness of grain, makes it ideal for products such as stakes, fencing and posts. The wood bonds well with a variety of adhesives. When dried and properly primed, it also takes paint and finishes extremely well. The screw and nail holding capacity is low, although this problem can be remedied by using special nails or by increasing the screw length. Its acidic properties cause corrosion of metals and black stain in the timber.

The species has the lowest volumetric shrinkage of any commercial softwood, and therefore possesses excellent stability for structural applications or for use in doors and windows. This is partly due to the low wood density and the low fibre saturation point of 18.5-23.0%.

Western red cedar is noted for its natural durability, a characteristic which is due to the very high extractive content of its heartwood. Extractive content is greatest in the most recently formed heartwood, with smaller amounts found in the sapwood. Extractives include compounds such as thujaplicins, thujic acid, methyl esters and lignins, mainly plicatic acid. Younger second growth trees have approximately half the thujaplicin content of their old growth counterparts (Nault, 1986, cited in Swan *et al.*, 1988). The thujaplicins are responsible for the fungitoxic nature of the extractives and thus the heartwood. These compounds are, however, soluble in water. As a result, western red cedar shingles and shakes used as roofing products in warm, damp climates, beneath hanging trees, or on roofs with low slopes, should be treated with some kind of preservative. Formerly, CCA (copper-chromium-arsenic) pressure treatment was favoured, but this method is now banned in some states in North America.

Western red cedar in thinner dimensions kiln-dries well, with little degrade. Thicker cross-sections may prove very difficult to dry, due to a tendency to hold patches of intense moisture. Care is therefore needed to avoid internal honeycombing and collapse. In British grown timber, such degrades are reported to occur in material grown on low or swampy ground. Collapse is also found to be associated with high extractive contents (Swan *et al.*, 1988). Splitting and checking are usually minimal and there is small movement in service.

The working properties of timber from Irish grown western red cedar are reasonably good. There are no reported problems in sawing logs using standard commercial machines and saws, although slabs from fluted butt logs are difficult to handle. Excessive taper leads to high conversion losses, necessitating the taper-sawing of logs.

During grading, timber tends to fall into the category of general structural use. Timber grown in Ireland and Britain contains many small knots which are often live. These knots tend to be distributed along the sawn timber, rather than grouped in regular whorls. It has been noted that small dead knots in boards from 20-30 year western red cedar were commonly rotten, leading to downgrading despite the surrounding timber being sound (Aldhous and Low, 1974).

Exceptionally high rates of dulling of cutting tools are observed with western red cedar, primarily due to the heartwood extractives. Cemented carbide-tipped saws (edger saws) known to cut Douglas fir for 40 hours blunt in less than half this time when sawing cedar cants (Kirbach and Chow, 1976).

Utilisation

Relative to other conifers on a world-wide basis, western red cedar possesses wood properties matched by few species. A high demand exists for specialised uses based on the intrinsic properties of the wood, namely its superior dimensional stability, durability and insulating qualities. These properties will ensure its continued importance and will perhaps lead to an increased emphasis on the species in the world market.

The principal market for western red cedar in its native north-western America is the shingle and shake industry, which accounts for 25% of the total amount harvested each year in British Columbia and the United States. Raw material for this market must come from old growth trees of at least 200 years of age, to ensure an adequate thujaplicin content. Its durability, ease of working and lightness make it a premier wood for this purpose. Shingles have better insulating properties than most roof coverings, with less air percolating through a shingle roof than through a tiled counterpart. In North America, western red cedar shingles have a working lifespan of approximately 30 years, increasing to 50 years with pre-treatment. In California, cedar shingles are now illegal due to the high risk of fire (Heald, pers. comm., 1997).

Given its visual appeal, western red cedar has a major potential for use in high quality end uses such as veneers, joinery and panelling. Its dimensional stability, ease of working and durability make it ideal for use in fences, balconies, patios, coffins and other outdoor applications.

Normal uses in Britain and Ireland include interior and exterior joinery, interior fitting, furniture and structural purposes. It is also used for garden sheds and beehives. Its appearance, insulation properties and durability make it a popular timber for the construction of saunas, a large market for which exists, particularly in Scandinavia.

Due to the major advances in wood building and treatment techniques, recent years have seen a resurgence in interest in wood as a light, strong and economical material for hull construction in the boat building industry. The organic nature of wood has an aesthetic attraction which resin, glass, PVC foam, steel and aluminium simply do not possess. Wood, stabilised and strengthened using epoxy glues, is now used as the core material, unlike traditional techniques where hardwood planking of mahogany and teak was the sole element of the outer hull. Western red cedar is commonly used as a core material and a demand for these hulls is slowly being created (Glenn, 1997).

Many houses in the United States are constructed predominantly of western red cedar. The timber is fitted together using a tongue and groove method and does not require any further adhesives or nails. The timber offers excellent insulation properties and adds a high aesthetic quality to the building. Irish examples of construction with western red cedar include the wood technology building in the University of Limerick and the chalets in Killykeen Forest Park, Co. Cavan. It is envisaged that these, together with the newly constructed wooden Coillte head office in Newtownmountkennedy, Co. Wicklow, will stimulate an increased interest in wooden architecture over the coming years.

Western red cedar is not regarded as a prime pulpwood species, due to its dark coloured heartwood, high extractive content and stringy, fibrous bark, all of which create difficulties during the pulping process. The timber is, however, used in Kraft pulps, where its fibre morphology enables the manufacture of a dense, tight sheet with good opacity characteristics.

The rich colour, lacy sprays and sweet smell make the foliage of western red cedar suitable for use in greenery displays and flower arrangements. This foliage market could be supplied from pruned material. Another series of properties which may add further value are chemicals present in the tree, including leaf oils and heartwood extractives, all of which have yet to be commercially exploited.

Conclusion

In *The Forests of Ireland*, published by the Society of Irish Foresters (FitzPatrick, 1965), the following comment was made in relation to western red cedar: "little planting has been done in state plantations because of a fungus *Keithia thujina*, which causes leaf blight in the nursery. If this problem can be surmounted Thuja is a useful tree on limestone gravel and for underplanting".

Western red cedar should be promoted on two target site types: the heavier lowland soils; and soils with a slightly alkaline nature. Growth rates are extremely high on these wetter sites, with a yield class of 28 recorded on experimental plots in Britain (Aldhous and Low, 1974). Western red cedar is well capable of overcoming vegetative competition and also acts as a soil improver.

While the species will rarely be able to compete with Sitka spruce on a productivity basis, timber prices for western red cedar should be higher, given its rarer intrinsic wood properties. This suggests the need to grow western red cedar for a niche market. Such a market would undoubtedly require the highest quality. Sawmillers frequently complain of the large number of knots and buttressing, but these defects probably arise from poor stand management, with the species often present as a suppressed understorey component.

A major argument against the planting of western red cedar is the lack of an existing market for its timber. Without a supply of timber, however, such a market cannot develop. In order to break this vicious cycle, it will be necessary to plant on the basis of a market emerging as future production comes onstream. In the United States, western red cedar sawlog prices appear to be increasing faster than those for other species. Western red cedar attains a higher price due to its durability, favourable working properties and low radial shrinkage. Aesthetics are becoming a major price factor, and western red cedar, with its rich heartwood colour, ranks highly in this regard. Also, the supply of old-growth western red cedar is decreasing in its native habitat, due to increased environmental pressure which is limiting logging in old-growth coastal forests.

As a shade tolerant tree, western red cedar is ideal for use in mixtures with other species, both broadleaf and conifer. Many Douglas fir plantations throughout the country suffer from very large branching and poor stem form. Western red cedar could help to ameliorate these stands, both improving the quality of the Douglas fir and adding to the stand value itself. The species should also be considered as a nurse in broadleaf plantations to encourage single straight leaders, to provide wind and frost shelter, and to suppress side branching. Its shade bearing status and fast growth create a potential for use in continuous cover forest management systems undertaken in sensitive areas where clearfelling would be unacceptable on environmental and/or amenity grounds. Western red cedar can also be mixed with Sitka spruce, the most dominant species in Irish forestry.

Provenance trials should be established to attempt to secure quality planting stock with reduced fluting and buttressing and improved growth rates, although little is known about the behavioural differences attributable to provenance.

Diversity is an important word in forestry practice in Ireland today. Western red cedar has a major potential role to play in species diversification, particularly as better quality lowland becomes available for forestry. Western red cedar should be one of those at the top of the list of alternative species in Ireland.

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General paper

The influence of wind on forestry in Ireland

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Summary
Wind is the major abiotic factor influencing Irish forestry. The most obvious manifestations of the impact of wind are windblow and windsnap. Every year, an average of 85,000 m^3 of timber are blown over. Wind can influence trees in other ways. It can alter some physiological processes within the tree, and contribute to the formation of reaction wood. Not all impacts of wind upon trees are harmful. Air movement plays a vital role in the reproductive process of many species, spreading seed and pollen. This paper outlines the influence of wind upon forestry in Ireland. It also attempts to predict the future impacts of wind in light of both probable climate change and changes in afforestation trends and practices.

Introduction – impacts of wind
Windblow and windsnap are the most obvious impacts of wind on forests in Ireland. Wind also has a major impact on tree growth and development.

Windblow and windsnap
Ireland has a severe wind climate compared to most other European countries. The country is situated in the path of Atlantic depressions which bring high rainfall and gusts, particularly along the west coast. Many of these depressions pass over the country each year, invariably resulting in the overturning of trees in forest stands. At less frequent intervals, severe storms hit the country, such as that experienced in most parts of Ireland during Christmas 1997. The gusting winds of over 40 m/sec associated with this storm were responsible for overturning or breaking trees in many forest sites, particularly in the south-west. Table 1 details the total volume of timber windblown in Irish State (and latterly Coillte) forests since 1980.

Much research, particularly in Britain, has focused on how and when wind will cause trees to overturn. In their work on the topic, Quine *et al.* (1995) show that windblow occurs when the overturning forces of the wind exceed the resistive forces of the tree. They argue that the resistance a tree within a stand offers to wind is a function of how well rooted it is and how much support it gets from its neighbours. The main determinants of rooting are soils and ground preparation techniques. Soils determine root depth. In free draining soils such as brown earths, greater depth of rooting is achieved, while in heavy textured soils such as gleys, root depth is restricted. Root spread is largely influenced by ground preparation methods. Savill (1983) highlights that attempts to reduce waterlogging in gley and

Table 1. *Volume of timber windblown within State forests from 1980-88, and Coillte forests from 1989-97. Source: Anon. (1980-88) and Anon. (1989-97a).*

Year	*Windblown volume ('000 m^3)*	*Year*	*Windblown volume ('000 m^3)*
1980	7	1989	111
1981	10	1990	167
1982	61	1991	80
1983	53	1992	125
1984	141	1993	92
1985	95	1994	155
1986	74	1995	42
1987	84	1996	not available
1988	101	1997	500

peat soils through intensive drainage by plough furrows introduced a new problem of restricted root spread.

When wind passes over a forest canopy, the behaviour of a tree within that stand is a function of the tree's height relative to stand height, stem stiffness, effective canopy drag area (Quine *et al.*, 1995) and taper (Petty and Worrell, 1981). The taller and less tapered the tree is, the more vulnerable it is to windblow (Savill, 1983). This is because the overturning moment exerted by wind of a given velocity on a crown is greater in a tall tree than in a short one. In contrast, the overturning moment is reduced with increased stem stiffness. The greater the effective drag area, the greater the risk of windblow. Trees with stiff foliage such as Sitka spruce (*Picea sitchensis* (Bong.) Carr.) have a higher drag factor than species with more flexible foliage. In addition, any operation which breaks the canopy, such as thinning or roading, will increase the size of the crown and hence, the drag area. Thinning also influences the resistance of stems to overturning by reducing crown contact. As previously mentioned, trees within stands gain much resistance to overturning through crown contact with their neighbours. This contact results in a damping effect and allows trees to dissipate the energy of the wind. Thinning reduces crown contact and renders the crop more susceptible to damage during the 2-5 year period when the canopy is re-closing (Savill, 1983). Thinning systems which cause major disruption to the canopy, namely systematic systems, have the greatest negative impact on crop stability (Hamilton, 1980). Delayed or heavy thinning also lead to windblow on vulnerable sites (Lynch, 1985). Damage to residual stems and compaction of soils during the extraction of thinnings compound the impact of thinning on stability.

It is clear that stand and site characteristics play a crucial role in determining the vulnerability of a stand to windblow. If rooting is restricted or the canopy disturbed, trees may overturn during the course of normal winter gales. If stands are well rooted, stem snap can occur during storms. Both types of damage have considerable financial implications for forest managers. Not only is wood damaged during windblow, but the cost of harvesting windblown material is high. Most significantly, rotation lengths are shortened as stands have to be prematurely clearfelled. The financial implications of shortened rotations are substantial.

Wood quality

Wind can lead to a change in wood properties within the tree. The formation of reaction wood within trees is attributed to the displacement of the stem from its normal vertical position (Haygreen and Bowyer, 1996). One of the common elements causing the tree stem to be displaced is wind, although poor root development, soil creep and phototropism play a part (Walker, 1993). If displaced for a period of time known as the presentation time, a gravitropic response is stimulated which leads to the development of reaction wood. Presentation time has been shown to range from 0.6-76 minutes by Westing (1965). In conifers, the reaction wood which forms is known as compression wood, and it develops on the lower side of leaning stems and branches. In hardwoods, reaction wood forms on the upper side of the leaning stem, and is called tension wood. Both types of reaction wood act to correct the lean of the stem (Walker, 1993). During the formation of compression wood, the tracheids on the underside of the leaning stem expand longitudinally, pushing the stem up. In the formation of tension wood, the fibres shrink, effectively pulling the stem up. Both forms of reaction wood have undesirable qualities. For example, compression wood will exhibit much greater longitudinal shrinkage than normal wood and is also less stiff (Desch and Dinwoodie, 1981). Tension wood has a tendency to warp upon drying and may collapse.

Reaction wood forms in an effort to return the displaced stem to the vertical position. The tree is, however, rarely returned to the vertical position (Timell, 1986). Instead, the stem may produce a distinctive sweep in the bole which effectively returns the apical meristem, and not the entire tree, to the vertical orientation (Telewski, 1995). The resulting curved stem proves difficult to saw and conversion rates are low (Williston, 1981). Reaction wood may also be found in vertical stems. This occurs when the displacement is small and the formation of reaction wood returns the stem to the vertical position with negligible sweep (Timell, 1986).

Tree growth

It has been shown that exposure to wind can lead to a reduction in height growth in a range of tree species. For example, Rees and Grace (1980) found that windspeeds of 8.5 m/sec resulted in a 22% reduction in height growth in lodgepole pine (*Pinus contorta* Dougl.). This reduction in height growth was attributed to a reduction in cell length within the tree arising from the mechanical impacts of wind, such as flexing and shaking. On the other hand, increases in diameter growth have been noted in trees exposed to wind. The swaying motion induced by wind leads to an expansion in diameter growth by stimulating an increase in production of the growth regulator ethylene, particularly on the leeward side. Consequently, the increase in radial growth tends to be asymmetrical, as the number of tracheids in the direction of flexure, or on the leeward side, increases (Larson, 1965).

The combined effect of increased diameter growth and reduced height growth is particularly evident in trees exposed for long periods to high winds, such as those growing on the edge of plantations as well as individual trees growing in exposed areas. Long term exposure tends to result in a more compact tree form with greater stem taper, shorter branches and smaller leaves (Telewski, 1995). These trees are more stable as the drag area is reduced. Many of these exposed trees can lack branches on the windward side where buds have been killed (Kozlowski *et al.*, 1991). With increasing altitudes and exposure, trees become progressively more deformed and stunted, with branches nearest to the ground tending to proliferate.

Much research has focused on the above-ground physiological and mechanical impacts of wind. Less effort has been expended specifically on the impact on tree roots. In much the same way that mechanical impacts of wind stimulate increased diameter growth in the stem, Fayle (1968) noted an increase in root growth where trees were subjected to the mechanical impacts of wind. He attached guy ropes to Scots pine (*P. sylvestris* L.) saplings which allowed only the tops of the plant to sway. Fayle found the annual ring widths of the lateral roots of the free-standing trees to be 75% greater than those of the guyed trees. This increase in diameter growth is greater on the tops and bottoms of lateral roots, leading to an increasingly eccentric cross-sectional appearance (Quine *et al.*, 1995). This can make the root three times more resistant to bending in the vertical direction than a root with the same cross-sectional area but circular in section.

Other impacts of wind

Wind has complex effects on photosynthesis (Kozlowski *et al.*, 1991). Leaves can became more clustered in response to exposure to wind. This effectively reduces the leaf display to irradiation and results in a reduction in the photosynthetic rate (Caldwell, 1970). Shorter needles have been observed on lodgepole pine trees exposed to high wind speeds (Rees and Grace, 1980), thereby reducing the photosynthetic area. Leaves and needles can also be torn and abraded as a result of wind. Rushton and Toner (1989) noted wind damage on sycamore (*Acer pseudoplatanus* L.) leaves. Some leaves had up to 46% of their leaf area damaged, while the majority had less than 10%.

The influence of wind on transpiration rates can vary according to species and wind speed. Kozlowski *et al.* (1991) describe a typical pattern of an initial increase in transpiration as wind speeds increase above 1.0 m/sec, followed by an eventual decrease. Stomata will eventually close in response to increasing wind speed for a combination of reasons, including leaf dehydration and leaf shaking (Kozlowski *et al.*, 1991), as well as a response to increased CO_2 levels at leaf surface when wind speeds are high (Mansfield and Davies, 1985).

Future impacts of wind in light of climate change and afforestation trends

This section examines how probable changes in climate, and changes in afforestation trends, will influence the impact of wind on forests in Ireland in the future.

Climate change

Some global climate change models predict an increase in both the frequency and intensity of storm events which give rise to catastrophic windblow (Emanuel, 1987). Conversely, Fitzgerald (pers. comm., 1990) quoted in Keane *et al.* (1991) suggested that wind speeds may decrease in the long term. Therefore, the implications of climate change on catastrophic wind events, such as that which occurred in Ireland in late 1997, is unclear. Predicting the occurrence of storms is quite difficult, although return periods for various wind speeds in Ireland have been estimated (Lowe, 1993). These return periods indicate the frequency of occurrence of certain wind speeds, based on historical records.

Afforestation trends

As a consequence of the current grant structure, afforestation is occurring and is likely to continue to take place on more lowland, sheltered sites than before. The predominant soil types on these afforestation sites are gleys and the majority will be planted with mixtures. In farm forestry sites, the afforested areas are likely to be small, as has been the case to date. There may also be a change to the silvicultural systems practised, as pressure to move away from the clearcutting system is exerted. These afforestation trends will have consequences for stand stability, as well as for stand growth and development.

Stability

The decrease in site elevation, as well as the increase in shelter, will result in lower wind speeds. Assuming that the mean altitude of forested sites was to fall from 350 m to 250 m, it is possible to estimate the reduction in mean wind speed. Tatter flags have been used in Britain and, to a lesser extent, in Ireland, to provide a cheap but effective means of estimating site windiness. Using tatter flag data from Scotland (Miller *et al.*, 1987), it is possible to show that the reduction of 100 m in elevation outlined above will result in a 13% reduction in windspeed. Mean wind speed is not a strong predictor of windblow risk. However, the strength of gusts or turbulence, which do influence windblow risk, is related to mean wind speed. Therefore, a reduction in mean wind speed should result in a reduction in the strength of gusts. Turbulence is also influenced by topography. If afforestation takes place on more sheltered areas than before, such as in valleys, a reduction in turbulence may follow. Much will, however, depend on the degree of wind funnelling in these areas.

Much of the recent afforestation has been with mixtures or with monocultures of broadleaves. It is quite extraordinary how little is known about crown and root development - both key components of stability - of the different species in a mixture, and how they relate to one another. Apart from the generalised view of differential rooting and stability, major differences have been demonstrated between the root systems of different broadleaf species, especially in their fine root density (Table 2). Little is known about the rooting behaviour of these species when grown in mixture. Mixtures also exhibit many complex activities in reaction to competition within the crown and proximity to neighbouring trees (Schütz, 1998). For example, crown development in larch (*Larix* spp.) trees is impaired when their crowns come close together. Therefore, one would expect less intertwining in larch stands (pure or mixed) than in mixed stands of beech (*Fagus* spp.) or spruce (*Picea* spp.), where the crowns intrude considerably before crown regression occurs (Pretzsch, 1992). This response to competition within mixed species stands will have implications for crown contact and hence, stability.

Table 2. *The rooting characteristics of some broadleaf species (Schütz, 1998).*

Species	*Depth*	*Rooting characteristics*
Beech (*Fagus* spp.)	Deep	Very fine and very dense near the soil surface
Oak (*Quercus* spp.)	Moderately deep and spreading	Fine
Ash (*Fraxinus* spp.)	Superficial	Coarse
Maple (*Acer* spp.)	Moderately deep	Dense fine root structure
Birch (*Betula* spp.)	Very deep	Coarse

The experience to date in Britain regarding conifer and broadleaf mixtures is that the broadleaf component remains stable and the conifer component, usually *Picea* spp., is at least as vulnerable as before. Savill *et al.* (1997) claim that such mixtures are possibly more vulnerable, as the deciduous trees are usually leafless at the times of major storms. This can cause pockets in the stand which lead to turbulence. These pockets in the canopy can also be quite wet during vulnerable periods.

There is increasing pressure in many countries to re-examine the silvicultural systems being used within forests. Large scale clear-cutting is becoming increasingly unacceptable for environmental, landscape and aesthetic reasons. Moving from the even-aged, clearfell systems currently used in Irish forests will have implications for stability. Quine and Miller (1990) recommend that if windblow risk is high (i.e. Hazard Class 5 or 6 using the British Forestry Commission model (Booth, 1977)), the clearfell system, with no thinning, is appropriate. They also consider the selection system to be appropriate in these sites, although it is unlikely to be widely applicable. In less vulnerable sites (Hazard Class 3 or 4), some of the shelterwood systems, such as the strip or the wedge, could be considered. However, any shelterwood system which creates irregular gaps in the canopy, such as the group shelterwood system, is unsuitable. This latter system should only be used in more sheltered areas (Hazard Class 1 or 2). While no objective assessment of windblow risk in Irish forests has yet been carried out, it has been estimated that over 75% of Coillte stands have at least a moderate windblow risk (Spaan, 1993). Therefore, any move to introduce alternative silvicultural systems, especially some of the shelterwood systems, could result in a decline in stability, particularly in Sitka spruce crops.

Growth and yield

In general terms, the decline in exposure associated with lowland sheltered sites will have a positive impact on yield classes. Worrell and Malcolm (1990) show that the general yield class (GYC) of Sitka spruce in Scotland increased by about 3-4 m^3/ha/year for every 100 m decrease in elevation. In addition, they showed that GYC values at any specific elevation were higher on inland and southern sites than on coastal and northern sites. This increase in yield class was attributed to the combined effect of increasing temperature and declining wind speeds. Worrell (1987) also quantified the impact of increased shelter on yield class. He showed that on hilltop sites with topex values of 0, GYC values were 2.5 m^3/ha/year lower than on sites of topex values of 30. Therefore, a reduction in altitude of 100 m and a move to more sheltered sites could result in an increase in yield class of at least 4 m^3/ha/year in the case of Sitka spruce stands.

Wood quality

A decline in wind speeds experienced at lower elevations may have consequences for wood quality. A reduction in taper may result in a consequent increase in conversion rates at the sawmill. In addition, the amount of reaction wood in planks sawn from trees growing on these lower elevation sites should be lower. One factor which counteracts these predictions regarding wood quality is the high number of edge trees in farm forests. Many farm forests are small. For example, almost 50% of private forests planted in 1995 were less than 6.0 hectares (Anon., 1995b). Consequently, the proportion of edge trees within these stands is high. If the areas afforested remain as low, the large taper of edge trees will lead to much greater wastage when sawn.

Future impacts of wind on existing stands

Aside from the changes afforestation trends might bring to bear on the occurrence of windblow, the situation on existing sites might be somewhat easier to predict. In the very short term, one might expect that damage due to endemic windblow (i.e. windblow arising from regular wind events) will increase. This is due to that fact that many Irish forests, planted 15-20 years ago, are reaching critical heights in relation to windblow. Many of these were established on relatively exposed sites which had been ploughed prior to establishment. In the longer term, however, the occurrence of endemic windblow should decrease as a result of the changes in silvicultural practices implemented in the mid-80s. For example, the majority of sites have not been ploughed prior to afforestation since that time. Instead, alternative techniques such as mechanical mounding or ripping are used. It is anticipated that trees established on mounded sites will be more wind-firm than those on ploughed sites, although there has been no scientific evidence to support this to date. Similarly, since 1985, systematic thinnings have been replaced by rack and selective thinnings, which should also improve stability. However, as root anchorage is a key component of stability, further work is necessary on identifying means of improving anchorage. Furthermore, while well-rooted trees are less prone to windblow, their susceptibility to windsnap increases. Therefore, an undesirable consequence of improvements to rooting may be an increase in the number of broken stems.

Other means to improve stability, some quite easy to implement, are available to foresters. These refer to the treatment of edges as well as the whole issue of forest design. The structure of the forest edge influences the amount and location of turbulence within the stand. If unsuitable, the edges can cause the winds hitting the stand to be deflected, leading to turbulence within 10 to 15 times the height of the edge. Any operations which allow the edges to filter the wind through the canopy decrease vulnerability. It has been recommended that a depth of 30-50 m from edges should be treated as shelterbelts (Kramer, 1980). Another means of reducing windblow risk is to take this risk into account when planning fellings coupes. The most vulnerable stands should be felled first, with care taken to avoid exposing other vulnerable stands to the prevailing wind (Quine *et al.*, 1995).

Quantifying stand vulnerability to windblow and implementing appropriate preventative strategies will play an important role in reducing the occurrence of windblow. Models which predict windblow risk have already been developed in Ireland and Britain. A number of these aim to guide management by suggesting appropriate preventative strategies for windblow. The best known of these is the British Forestry Commission Windblow Hazard Classification (Booth, 1977), which has been revised a number of times since its development (Miller, 1985). The latest version of this model (Quine and White, 1993) predicts the onset of windblow based on an assessment of the following five factors: soil, location, exposure, elevation and aspect. While this latest version is an improvement on previous models in that it accounts for the funnelling effect of topography on wind, it is deterministic similar to previous versions (Quine *et al.*, 1995). Therefore, it gives no indication of the range of possible outcomes. For example, it does not indicate what percentage of high risk sites will actually experience windblow. Recent efforts in Britain are attempting to address this problem. A new model is being developed which estimates the probability of windblow occurring rather than stating a precise height at which damage will occur (Quine, 1996).

Currently in Ireland, estimates of stand vulnerability to windblow are made subjectively by forest managers, with thinning and clearfelling decisions made accordingly. While local knowledge is crucial in determining windblow risk, providing forest managers and forest developers with an accessible and objective means of assessing windblow risk is a priority. A more objective means of assessing windblow risk would result in greater consistency and would be a very useful decision support tool for foresters. Work commenced in 1997 on a project to develop a windblow model for Ireland. This project, funded by COFORD, involves researchers from the Forestry Section of the Department of Crop

Science, Horticulture and Forestry, UCD, Coillte, Teagasc and Trinity College Dublin. The aim is to integrate the model into databases in the Forest Service as well as in Coillte. In this way, a user-friendly model accessible to all potentials users will be developed.

Conclusion

Wind has a major impact on forests in Ireland. It causes trees to blow over, changes wood properties, and has a major influence on tree growth. It is known that the magnitude of this impact is influenced by the site on which the trees are growing, the species of tree and the silvicultural practices applied to the stand. However, limited research has been conducted to quantify how these factors interact with each other and with wind to influence tree growth and stability. It is hoped that the new model being developed for Irish conditions, described above, will quantify some of these interactions.

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General paper

Getting the species and provenance right for climate change

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Summary
Current predictions of climate change are based on simulations using global circulation models of the atmosphere. Without validation of the results of these models, we have no idea of whether or not their predicted climate changes will take place. Greater effort in determining the accuracy of the models is needed, given that they are the only method currently available to predict the impact of increased CO_2 levels on the climate.

In the absence of proof of current climate change, it would be prudent, for now at least, to consider the predictions of increased average annual temperatures and changes in precipitation patterns. Similar changes have taken place in the past, but the fear now is that these changes will take place more rapidly in the future. The predicted increase in winter temperatures will probably mean less frost damage, but will also affect the date of bud break, which will impact on some species more than others. Genetic variation in traits associated with adaptation to local conditions, such as date of bud break, date of bud set, optimal temperature for photosynthesis, pest resistance and drought tolerance, exists not only at the species level, but also at the provenance, family and individual level. Therefore, by identifying highly adaptable sources of material, it is possible to develop new varieties which will be better able to cope with future climatic conditions than current material. This information is best obtained from classical provenance experiments. Climatic changes will probably result in changes in the natural distribution of forest tree species, and may limit the use of some species in plantation forestry. The impact on Sitka spruce (*Picea sitchensis* (Bong.) Carr.) should be minimal, but a number of other commercially important species, such as Norway spruce (*P. abies* (L.) Karst.), Scots pine (*Pinus sylvestris* L.), common beech (*Fagus sylvatica* L.), common ash (*Fraxinus excelsior* L.) and sessile oak (*Quercus petraea* (Mattuschka) Lieblein) may be adversely affected. What is now required is validation that the current models are correct, followed by a commitment, together with a plan, to do something about those species at greatest risk.

Introduction - should we believe the models?
Although climate change seems to be something we have been hearing about for the last 10 years or so, it is not something new. It has been taking place almost since the formation of the earth. Indeed, the climate of Ireland for over 90% of the last 2.5 million years has been very cold, with an average air temperature 6°C colder than today (Coxon, 1997). The current problem arises from the unprecedented rapidity of the present predicted change. In fact, it has been suggested that dramatic changes in the climate will take place during the rotation length of a single crop (Schmidtling, 1994). Such rapid change will very likely put some species and seed sources at risk.

During the last 30 years, a variety of changes in the climate have been predicted, but for different reasons. In the 1970s, natural global cooling was predicted to result in a new ice age, while in the 1980s, the threat of global nuclear war led to predictions of "nuclear winter" (Coxon, 1997). Now in the 1990s, the main concern is global warming, or perhaps more accurately, climate change, resulting from increased CO_2 emission.

Climate change predictions are based on increased levels of atmospheric CO_2 incorporated into global circulation models (GCM) which are based on physical conservation laws to predict future environments. Depending on the initial inputs, a set of new conditions are calculated using the models which provide the basis of subsequent conditions. For this reason, very slight alterations either in the initial conditions or in the model itself can have a profound effect on the results. In addition, as these models employ a relatively large grid area (5° latitude x 5° longitude), they do not allow for predictions of climate changes at the local level (Loehle and LeBlanc, 1996).

The scientific method operates on observations of nature which are used to develop hypotheses which are then tested. Hypotheses which are consistent with new observations are accepted as long as they agree with the data, while hypotheses that do not are rejected. Mathematical models are a way of studying complex systems and developing hypotheses for testing. Such hypotheses should be subject to testing and either accepted or rejected, but if not testable or not tested, they should not be assumed to be correct. For a model to be useful, it must be accurate in its predictions of future conditions when compared with actual observations. Unfortunately, such validation based on observations of climate change are not currently possible (Hanninen, 1995). The use of GCM models, which have been described as "greatly simplified models" (Loehle and LeBlanc, 1996), to make predictions of a future earth's climate without validation, may be giving us very inaccurate results. A good discussion of the limitations of models to predict future climate changes is made by Reifsnyder (1989).

Future climatic conditions

Nevertheless, for the purposes of this discussion, the predictions of changes in the climate based on current models will be assumed to be correct. Basically, these models predict a doubling of CO_2 levels by the year 2050, resulting in an increase in average world temperature of between 1.5- 4.0°C (Loehle and LeBlanc, 1996). In addition, warmer night temperatures and warmer winter temperatures are anticipated. Sweeney (1997) has provided information on what specific changes may occur in the Irish climate, which include an average annual temperature increase of 1.0°C, an average winter temperature increase of 0.5°C, and an average summer temperature increase of 1.5°C. Changes in national precipitation rates are also predicted, but local changes are very difficult to predict. Although predictions in future precipitation patterns are less accurate, it is expected that there will be little overall change in annual precipitation in Ireland, with a 5-10% increase in average winter rainfall and a 5-15% decrease in average summer precipitation.

The implication of these changes in climate on forests has received much attention. Warmer winters may result in increased respiration, increasing stress levels in conifers (Loehle and LeBlanc, 1996). Warmer winter temperatures may also prevent species from fulfilling their winter chilling requirements (necessary for dormancy release), alter flowering times, seed production and seed germination (and thus natural regeneration rates), affect insect and disease levels (warmer winters may mean lower winter mortality rates as well as more insect generations/year), and increase summer drought stress (Ledig and Kitzmiller, 1992). In light of these possible changes, we now need to consider if and how forest tree species will be able to cope with them.

Adaptation

If such changes in local climate do take place, they will have an effect on the species as well as the provenances or seed origins that we plant. Species trials are designed to identify species which are best adapted to local conditions. Provenance experiments identify patterns of variation within a particular species, and allow the identification of the best sources of seed for local use (Ledig, 1991). Although it is usually assumed that a species range is determined by climatic conditions which limit where a species is able to survive, this assumption is not true (Loehle and LeBlanc, 1996). A large number of 'exotic' species have demonstrated more vigorous growth in environments very different from their natural locations, due to their ability to adapt to the new conditions (Beuker, 1994). This ability to adapt to new environmental conditions results from genetic variation within the species.

The belief that every individual within a species has identical environmental limitations and tolerances is not correct (Ledig, 1991). Genetic variation in traits relating to the ability to adapt to different environments, such as date of bud break, date of bud set, optimal temperature for photosynthesis, drought tolerance, pest resistance and ability to compete (Perry, 1979), result in differences in adaptability in different species, provenances, families and even clones. Even in very poorly adapted species or provenances, rarely is there a complete failure. Usually a few individuals will survive. They may not thrive and reproduce, but some do have the ability to survive. Adaptability thus permits an individual to endure a much broader range of environmental conditions than it would normally encounter. The fact that most forest trees contain considerable amounts of genetic variation helps to makes them very adaptable (Eriksson *et al.*, 1993).

The belief that natural selection produces individuals most suitably adapted to local conditions has led to the incorrect assumption that local material is best. As selection is only for individuals that will survive and reproduce under local conditions, there is no need for optimal adaptation to local conditions. Nature is not interested in optimisation, so maximum fitness to a particular environment simply does not exist (Eriksson *et al.*, 1993). Adaptation is conservative so that selection is made for the fewest traits needed for the individual to survive and reproduce in the new environment. As a result of this very conservative natural selection, most individuals fail to take full advantage of the local environment. Selection for protection against late spring frosts by late bud break may result in a loss in the ability to take advantage of the full growing season. The transfer of provenances or origins from mild conditions may increase their ability to more fully utilise the growing season, but they may be at an increased risk of damage due to late spring or early autumn frosts (Ledig and Kitzmiller, 1992).

In addition to genetic variation in adaptability at the species level, adaptation also occurs at the provenance level, at the family level and at the individual level. To focus on provenance as the best genetic leverage point to cope with climate change is perhaps too simplistic. At the individual level, several late flushing (late May) rapid shoot elongating clones of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) have been identified in clonal trials. This behaviour has not been observed at the family or provenance level, even though these individuals probably exist. For this reason, the original title of this paper has been altered from "Getting the provenance right for climate change" to "Getting the *species and* provenance right for climate change".

Getting the species right

Although it may appear at first that a major benefit of increased average annual temperatures would be a reduction in frost damage, another aspect of winter cold may play a pivotal role. A series of studies on 15 UK species (Cannell and Smith, 1983; Murray *et al.*, 1989) showed that an increase in average winter temperatures resulted in a delay in bud burst for many species. This was due to the fact that trees require a certain number of chilling hours (hours below +5°C) in order to be able to break bud when conditions permit in the spring. An increase in average winter temperatures would lead to a delay in accumulating the necessary number of chilling hours, thus delaying bud break. Different species have different chilling requirements, as reflected in variations in the average date of bud break between species (Kramer, 1994). Data on the variation in the chilling requirements of different species (Table 1) has been used in modelling the impact of climatic warming on both the probability of spring frost damage (Kramer, 1994) and the adaptive ability of northern European forest tree species to both current and future climatic regimes (Sykes and Prentice, 1995; Sykes *et al.*, 1996). Species which require a long rest period (below +5°C) would be most affected by warmer winter temperatures.

Table 1. *Differences in duration of the rest and the quiescence periods (days) in different European tree species (Kramer, 1994).*

Species	*Rest requirement*	*Quiescence requirement*
European larch (*Larix decidua* Mill.)	101	65
Downy birch (*Betula pubescens* Ehrh.)	105	64
Common beech (*Fagus sylvatica* L.)	128	50
Pedunculate oak (*Quercus robur* L.)	126	56
Sessile oak (*Q. petraea* (Mattuschka) Lieblein)	139	50
Common ash (*Fraxinus excelsior* L.)	149	39
Norway spruce (*Picea abies* (L.) Karst.)	117	72
Scots pine (*Pinus sylvestris* L.)	122	68

These projected species responses to global warming suggest that the climatic conditions resulting from a doubling of current CO_2 levels by the year 2050 could result in dramatic changes in the adaptability of several commercially important species to the new climatic conditions in Ireland. It appears from a comparison of current and future species distribution patterns (Sykes and Prentice, 1995; Sykes *et al.*, 1996) that Norway spruce (*P. abies* (L.) Karst.), Scots pine (*Pinus sylvestris* L.), common ash (*Fraxinus excelsior* L.), common beech (*Fagus sylvatica* L.) and sessile oak (*Quercus petraea* (Mattuschka) Lieblein) may not be as successful under a warmer Irish climate, due to increased competition from better adapted species. This assumption is, however, based on overall species requirements, and does not take into consideration natural genetic variation in chilling requirements possible at the provenance, family or even individual level.

Interestingly, for Sitka spruce, average warmer winter temperatures on lowland sites would result in bud break at a slightly later date than that under current conditions (Murray *et al.*, 1989). A delay in bud break might slightly reduce the probability of damage by late spring frost, but would also reduce the length of the growing season. On colder upland sites, where the effect of increased average winter temperatures would be less, there would be less of a delay in the date of bud burst than on the warmer lowland sites (Murray *et al.*, 1989). The same would be true for Norway spruce, Scots pine, common ash, common beech and sessile oak. On cool upland sites, these species would be more adversely affected by warmer winter temperatures than on lowland sites.

Getting the provenance right

Provenance experiments provide valuable insights into the performance of different seed sources from the entire species range (Matyas, 1994; Schmidtling, 1994). In Sitka spruce, if bud break is delayed as a result of a warmer winter climate, it then becomes important to use provenances which will take full advantage of the reduced growing season. Certainly the more southerly provenances such as Washington and Oregon, which begin to set bud in late October or November, would be more productive than Queen Charlotte Island material, which sets bud in late August or September.

Provenance experiments with Norway spruce (Krutzsch, 1992) have shown that this species is very adaptable to a wide range of sites. Across 10 European trial sites, the south-eastern sources from the Carpathian and Bihor Mountains in Romania have consistently performed the best. As Norway spruce is basically a continental species, it does tend to have problems in exposed oceanic conditions, one example being the 'top-dying' syndrome observed in Ireland, Scotland and Denmark. With increases in winter temperature resulting in higher winter respiration rates and an increased likelihood of summer drought, the Romanian provenances of Norway spruce in Ireland may be exposed to conditions to which they are unable to adapt. A provenance experiment involving 1,100 Norway spruce provenances planted on one site in 1968 has already provided information on the date of bud break and the growth and form of the species from all parts of its natural range. This information should help in identifying the best adapted seed sources.

In Scots pine, the situation is different, with local material usually outperforming any other provenance (Giertych, 1979). Currently, the recommended seed sources of Scots pine for Ireland are Scottish provenances. With an increase in average temperatures and drought, more eastern sources may, however, prove to be better adapted. Unfortunately, the only provenance experiments with Scots pine in this country are limited to Scottish and Norwegian provenances.

Results from a beech provenance trial planted in 1995 has already shown that eastern provenances (Slovakia and the Czech Republic) and high elevation provenances break bud first, while western provenances (Dutch, French, British and Irish) are the last to flush. While early bud break could result in rapid height growth, it is also at greatest risk to late spring frost damage. Thus, while western European sources of beech may be most tolerant to late spring frosts, they will flush late in the spring under warmer winters, and will therefore be less able to compete with other species.

Regarding oak, an IUFRO oak provenance trial comprising Irish, British, French, Dutch and German provenances, was planted in 1990. Once again, the Dutch, British and Irish provenances were the last to break bud. As with beech, late flushing could become a liability with warmer winters.

There have been no provenance trials comparing common ash from Ireland with any other seed sources. While it has always been assumed that Irish ash is best, as shown in the examples of beech and oak above, warmer winters may result in later flushing and thus, reduced growth and productivity.

What are others doing about it?

Concerns about climate change have been expressed by tree breeders in other parts of the world, such as New Zealand and Canada. In New Zealand, the major species, Monterey pine (*P. radiata* D. Don), prefers a moist, warm site for optimal growth. These conditions are also optimal for fungal growth which could result in increased disease problems. Higher levels of CO_2 could increase pine growth rates and may also increase the nutrient requirements of the species. Increased storms would increase the amount of wind damage, thus reducing the volume of marketable timber (Grace *et al.*, 1991).

The New Zealand Monterey pine breeding programme can produce a new variety of pine in 12-14 years. This may be rapid enough to develop new varieties adapted to the changes in the climate. Results from tree improvement tests in New Zealand suggest that good individuals will do well on a range of sites, creating the opportunity to develop good, all-round performers which should do well even under altered environmental conditions. There are, however, limits to genetic variation in any species, and alternative species may be necessary for sites which are no longer suitable for Monterey pine (Grace *et al.*, 1991).

Tree improvement work with black spruce (*P. mariana* (Mill.) Britten, Sterns and Poggenberg) in Canada has employed screening of genetically improved material in growth chambers under predicted environmental conditions. Results so far show that black spruce material selected for good growth under current conditions will do well under future conditions (Wang *et al.*, 1994).

Other work in Canada has suggested that some alterations in the mixture of the major species may be necessary to cope with projected environmental changes. Shorter rotation length species would provide the greatest flexibility. In addition, hybrids between native and introduced species, such as hybrid larch (*Larix* x *eurolepis* Henry), might be an option (Fowler and Loo-Dinkins, 1992).

Other options

The uncertainly of whether or not dramatic changes in the climate will occur suggests caution in making radical changes in species and provenance selections. If provenance changes are to be made, one interesting suggestion is to mix material from both currently used provenances and provenances believed to best match future conditions (Ledig and Kitzmiller, 1992). Similarly, selected species mixtures might be a good option, to ensure continued forest productivity in a changing climate. We need to look closer at Norway spruce, Scots pine, common ash, common beech and sessile oak, to determine whether or not they will actually be at risk, as suggested by some researchers.

Should breeding programmes immediately embark on breeding material specifically designed for future environmental conditions? In light of the fact that future environmental conditions can not be accurately predicted, this would be a difficult task. There are two options: breed for specialist varieties designed specifically for future conditions; or breed for generalists which have the adaptive capacity to cope with uncertainty. From the evidence from New Zealand (Grace *et al.*, 1991) and Canada (Wang *et al.*, 1994), it appears that improved material selected for good growth under current conditions may provide a reasonable base from which to develop more general purpose adaptable varieties for the future.

Conclusion

The assumption that global circulation models currently available are capable of providing accurate predictions of the climate 50 years into the future, is a large one. Models are tools for the generation of hypotheses which need to be validated in light of observed data. Validation of these models will require time, but until validated, these models need to be viewed with some scepticism.

In the absence of validated models, we can only assume that they may be correct and consider the implications of the climatic changes they predict. For Ireland, slightly warmer average winter temperatures and increased average summer temperatures (Sweeney, 1997) will have important implications on the completion of chilling requirements in a number of species. Some species, such as Norway spruce, Scots pine, common ash, common beech and sessile oak, may be less productive and subject to greater competition in the predicted Irish climate. Although this premise ignores the fact that significant genetic variation in adaptive traits exists in all species at the species, provenance, family and individual level, this does provide a short list of species for immediate attention.

Current and future provenance trials should be useful in identifying seed sources which may be better able to cope with a reduced chilling period, perhaps by moving from native or naturalised sources to more southerly material. Although provenance experiments can be a very long-term activity, results from a recently established (1995) beech provenance trial have already provided information on the pattern of bud break in the species which will perhaps be most affected by climate change. This illustrates that provenance experiments can provide useful information in both the short and long term, depending on the traits of interest. Very limited information on provenance is available on Scots pine in Ireland, and no specific information is available on sessile oak or common ash. It may be possible to access information from other provenance experiments in Europe, to identify sources of highly adaptable provenances or families for testing under Irish conditions.

It is also possible that evidence from other tree improvement programmes is correct, and that material which has been genetically improved (selected and tested) under current conditions will also be well adapted to future conditions. If this is true, we should initiate or accelerate our tree improvement efforts in those species at risk.

Natural genetic variation will provide the range of adaptive traits necessary to combat the potential influence of climatic changes in the future. Techniques exist to attack these problems. Perhaps what is most needed now is both clear evidence that the climate is changing, followed by a strong commitment that something needs to be done to offset the effect of these changes on Irish forests.

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General paper

Climate change – the evidence so far and predictions for tree growth

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Summary

Atmospheric carbon dioxide concentrations will continue to rise for the foreseeable future at a rate dependent on human activity and the success of the emission control policies prescribed at the United Nations Convention on Climate Change. Evidence suggests that this and other 'greenhouse' gases have already influenced our climate and may have had an effect on forest productivity during the course of the twentieth century. Predictions of future climate are now available, and the influence of climate change on forest growth can already be modelled through an analysis of spatial clines in climatic variables such as temperature and rainfall. The direct effects of atmospheric carbon dioxide concentrations and interactions with a changing climate are, however, more difficult to model. For these purposes, physiological or process-based models are required, in which the response of individual physiological processes to changing carbon dioxide concentrations is determined in controlled environment facilities and then parameterised for input into the growth models. The individual processes of these models can be validated by comparison with whole canopy water vapour and carbon dioxide flux data, while the growth predictions can be partially validated using historic climate and yield data. Only when these models are finalised and validated can we reliably predict the impact of climate change on forest growth.

Climate change and prediction of future climate

The temperature of the earth's atmosphere and surface is maintained at values favourable to life through the balance of incoming and outgoing solar radiation. Much of the heat from incoming solar radiation is radiated back into space. The presence, however, of greenhouse gases in the atmosphere results in the absorption of outgoing heat, particularly in the infrared part of the electromagnetic spectrum. This 'greenhouse effect' is important in maintaining favourable temperatures, but if the concentrations of greenhouse gases increase in the atmosphere, the warming effect will be enhanced, resulting in anthropogenic climate change – global warming. Greenhouse gases are therefore those which absorb radiation in the infrared part of the electromagnetic spectrum and are present in the atmosphere. They include carbon dioxide, water vapour, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs). Of these gases, the concentrations of carbon dioxide (Keeling *et al.*, 1995; Figure 1), methane and CFCs have increased significantly in the atmosphere as a result of human activity.

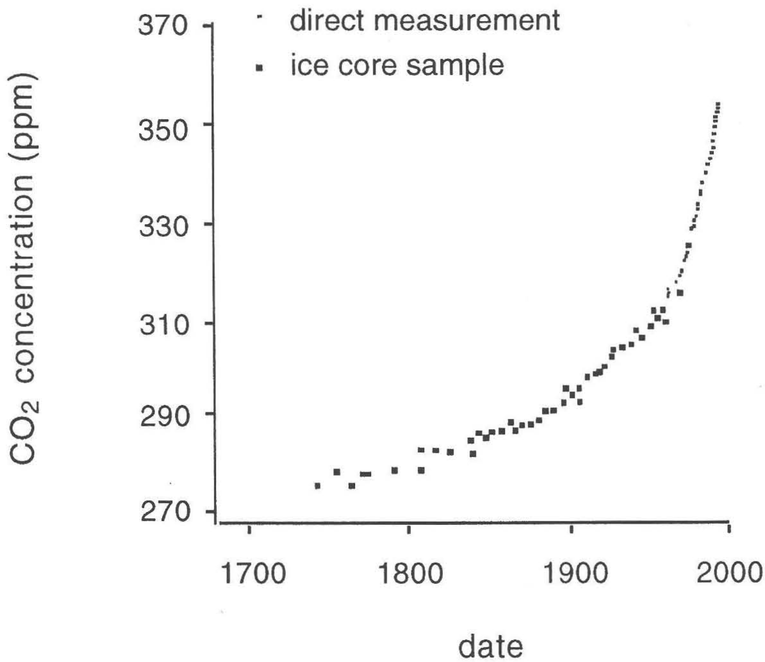

Figure 1. *Atmospheric CO_2 concentrations since 1850. Redrawn after Friedli* et al. *(1986) and Keeling* et al. *(1995).*

It is now widely accepted that anthropogenic climate change is occurring, and the UN Intergovernmental Panel on Climate Change (IPCC) has concluded that "the balance of evidence suggests a discernible human influence on global climate" (IPCC, 1995). Over a number of years, the evidence from average global surface temperatures has become increasingly clear, and 1997 was the hottest year on record to date. Average global temperatures have risen by 0.6°C in the last 130 years, and general circulation models (GCMs) are now able to predict the impact of increasing greenhouse gas concentrations on global temperatures.

In order to understand the potential impacts of climate change, it is essential to have accurate predictions of future climate at the regional scale. Internationally, predictions or scenarios have been provided by the IPCC. Within the UK, these have been provided by the Meteorological Office at the Hadley Centre for Climate Prediction and Research, at a spatial resolution of 10 minutes (i.e. 10 km grid squares). Predictions at this scale are clearly very useful for predicting impacts on vegetation. Mean winter temperatures and average precipitation in millimetres per day are available for the 1961-90 baseline period and for the years 2025, 2050 and 2100. This work forms the basis of the scenario which the Climate Change Impacts Review Group (CCIRG) of the UK's Department of the Environment, Transport and the Regions (DETR) has assessed since 1995. The relatively small changes in temperature and rainfall (Table 1) will lead to much larger changes in potential evapo-transpiration, while the annual distribution of rainfall and the occurrence of storm events may also change. Projected temperature increases should therefore not be viewed in isolation.

Table 1. *Predicted changes to the climate of south-east and north-west UK for 2050, representing the UK Climate Change Impacts Review Group scenario (CCIRG, 1996).*

	South-east		*North-west*	
	Summer	*Winter*	*Summer*	*Winter*
Temperature	+1.8°C	+1.8°C	+1.2°C	+1°C
Rainfall	-9%	+10%	+5%	+3%
Potential evapo-transpiration	+30%	+100%	0%	-25%
Mean windspeed	+2%	+6%	+2%	+2%
CO_2		+57% (525 ppm)		

Impacts on forestry

The changes predicted in the scenario outlined in Table 1 would have very important implications for forestry. The occurrence of late spring frost is already a problem for forestry in parts of the UK, restricting the use of some tree species and provenances (Murray *et al.*, 1994). Similarly, increased windiness, particularly storms, could have devastating effects, as exemplified by the 1987 storm in southern England. One important feature of UK forestry relevant to these impacts is that a number of introduced species are used widely as they grow rapidly over short rotation lengths. A second important feature is that the native species have ranges which span considerable climatic differences. For the introduced species, seed origins (provenance) are used to select for the most appropriate genotype to maximise growth potential. Therefore, a shift of seed origin is a possible proactive response to climate change. For example, for Sitka spruce (*Picea sitchensis* (Bong.) Carr.), it is possible that more Oregon or Washington provenances should be planted in place of the Queen Charlotte Island provenance. In the case of native species, the majority do grow over a wide range of climatic conditions. This wide genetic base should therefore allow for adaptation to a changing environment. Natural selection may, however, not keep pace with the rate of environmental change, and the selection of non-native provenances should be considered.

Cannell *et al.* (1989) have listed tree species which are currently not widely planted but which might show enhanced growth under a warmer UK climate (Table 2). These include *Eucalyptus* spp. and *Nothofagus* spp. which are native to regions with a warmer climate than that currently experienced in the UK. These authors have also listed species which are currently used but which may perform better or worse should the predicted changes occur. Those which might grow better are species such as beech (*Fagus sylvatica* L.) and small-leafed lime (*Tilia cordata* Mill.), for which the northern limit for growth is determined by temperature and passes across the UK. Species which may grow less well include grey alder (*Alnus incana* (L.) Moench), bird cherry (*Prunus padus* L.) and willow (*Salix* spp.), which will suffer from higher soil moisture deficits. In addition to temperature and extreme events (late spring frost and storms), there are a number of other environmental factors which are changing and which may influence tree growth and forest productivity. These include UV-B, air pollutants (particularly nitrogen and ozone in the lower atmosphere) and drought, and the interactions of these factors with forest insects and pathogens.

Table 2. *Potential impact of predicted climate change on the growth of existing forest species, and new species for consideration under such conditions (Cannell* et al.*, 1989).*

Species which may grow better	*Species which may grow less well*	*New species to consider*
Fagus sylvatica L.	*Alnus incana* (L.) Moench	*Acer* spp.
Ilex aquifolium L.	*Prunus padus* L.	*Eucalyptus* spp.
Nothofagus spp.	*Salix pentandra* L.	*Fagus orientalis* Lipsky
Populus alba L.	*Sorbus aucuparia* L.	*Ficus carica* L.
Quercus rubra L.		*Juglans nigra* L.
Robinia pseudoacacia L.		*Platanus orientalis* L.
Tilia cordata Mill.		*Populus* spp.
Tilia platyphyllos Scop.		*Prunus dulcis* D.A. Webb
		Prunus serotina Ehrh.
		Quercus ilex L.

Direct effects of elevated CO_2 and interactions in the effects of CO_2 and other factors

While the increase in the concentration of carbon dioxide in the atmosphere is probably the primary driving force for the greenhouse effect and changing climate, the concentration of CO_2 also has direct effects on plant growth, since it is the plant's source of carbon. These direct effects of elevated CO_2 also impinge upon the response of tree growth to some of the other environmental factors listed above. It is important to be able to predict the magnitude of these responses, and this can be investigated directly through experimental research. The Forestry Commission has set in place a research programme using open-top chambers at upland and lowland sites, to investigate the response of tree growth to elevated CO_2 alone, and also, the interactions of these responses with ozone, drought and nutrition for several tree species. The experiments have shown that the growth response to CO_2 alone is species specific and highly dependant on the other factors included in the experiments (Ceulemans and Mousseau, 1994; Broadmeadow *et al.,* 1996). Figure 2 demonstrates that for sessile oak (*Quercus petraea (*Mattuschka) Liebl.), there is a large positive growth response to elevated CO_2, which also ameliorates the detrimental effect of elevated ozone pollution. Both Scots pine (*Pinus sylvestris* L.) and common ash (*Fraxinus excelsior* L.) showed little response to ozone, while the CO_2 enhancement of growth was minimal in common ash and small in Scots pine, relative to sessile oak.

These observed responses of growth to elevated CO_2 represent the integrated effects of a number of physiological processes. The direct enhancement of photosynthesis in elevated CO_2 is evident (Figure 3). If these measurements are made at saturating CO_2 concentrations representing potential photosynthetic capacity (Figure 4), complex interactions between ozone pollution, water supply and CO_2 are observed. Ozone severely reduces photosynthetic capacity, an effect which is completely reversed by elevated CO_2 under conditions of drought, but not irrigation. This is likely to be a result of stomatal closure in response to increased internal CO_2 concentrations (Stitt, 1991) reducing the effective ozone dose, a response diminished by irrigation. A combination of direct CO_2 enhancement of photosynthesis and reduced stomatal conductance generally leads to increases in water use efficiency (Guehl *et al.,* 1994), as shown in Figure 5, which may counteract the predicted reductions in water availability. Under conditions of poor soil

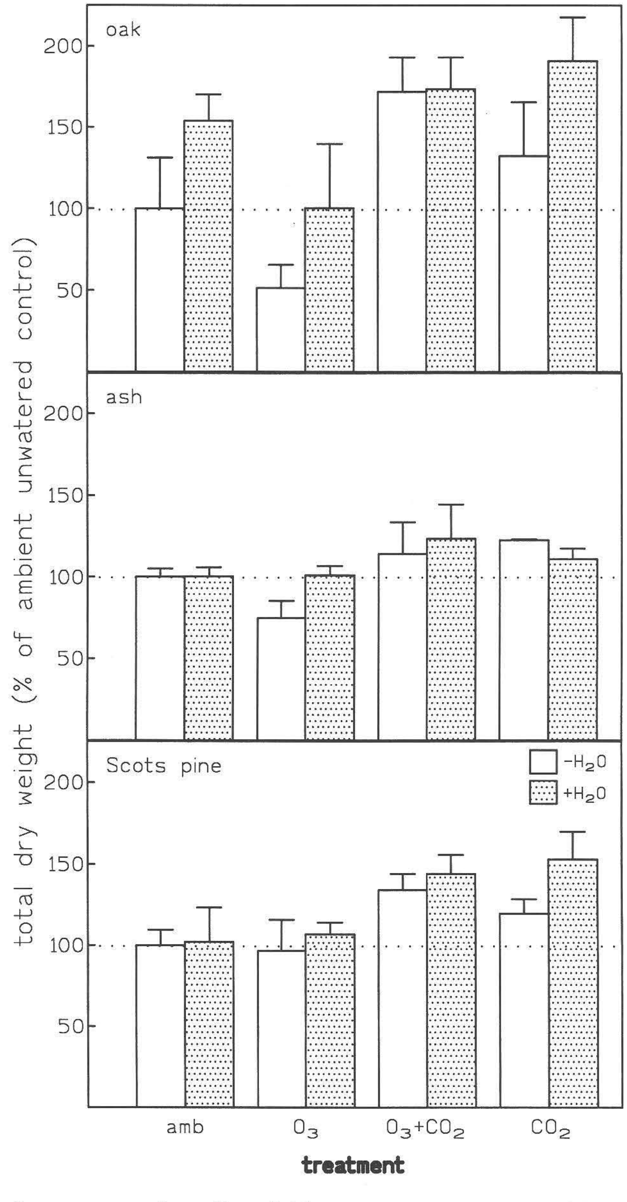

Figure 2. *Growth responses of sessile oak* (Quercus petraea *(Mattuschka) Liebl.*), *common ash* (Fraxinus excelsior *L.*) *and Scots pine* (Pinus sylvestris *L.*) *to treatments of elevated CO_2, ozone and irrigation. Trees were exposed for 3 years to factorial treatments of ambient (350 ppm) or elevated (700 ppm) CO_2, ambient or elevated (20 ppb overnight rising to 100 ppb for 4 hours/day during the growing season) ozone, and 10% or 20% volumetric soil moisture. Values are expressed as a percentage of the unwatered ambient control (100%), with error bars representing half the difference between duplicate chambers.*

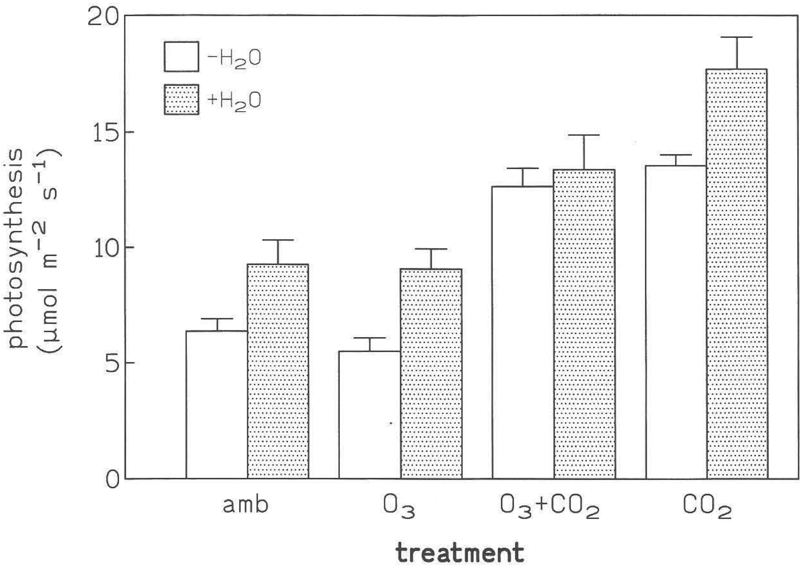

Figure 3. *Photosynthesis of oak exposed to elevated CO_2, O_3 and irrigation as described in Figure 2. Measurements were made using a LCA-3 gas exchange analysis system (ADC Ltd., Hoddesdon, Herts, UK). Values represent the mean (+/- 1 standard error of the mean) of 7 days' analyses during the 1995 growing season, with 10 measurements made per treatment per day.*

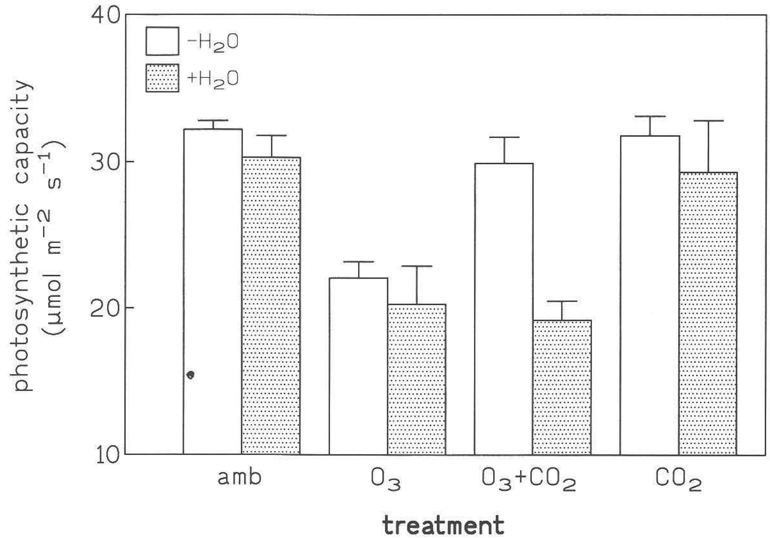

Figure 4. *Light and CO_2 saturated rates of photosynthesis in oak. Measurements were made at 1600 ppm CO_2 on 4 days during the 1995 growing season. Values are the mean of the 4 days' analyses (+/- 1 standard error of the mean), with 10 analyses per treatment per day.*

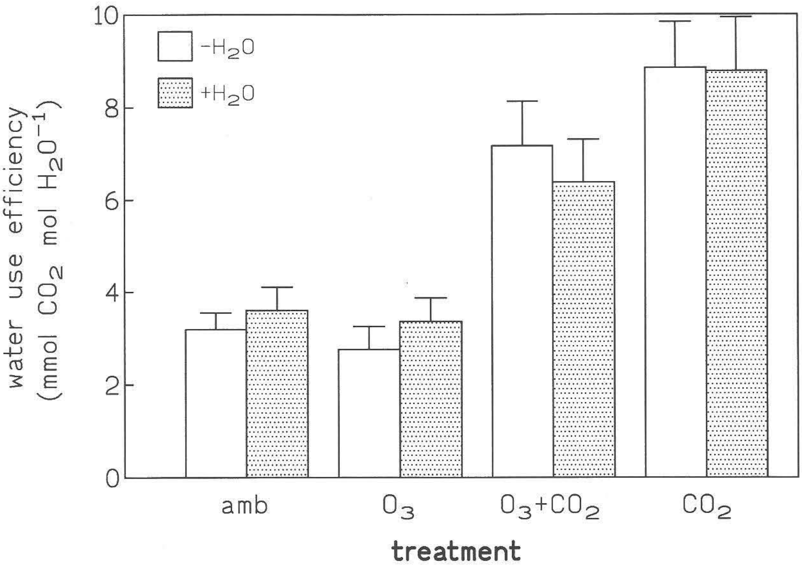

Figure 5. *Water use efficiency in oak, expressed as mmol CO_2 assimilated per mol H_2O transpired. Measurements were made concurrently with those of photosynthesis shown in Figure 3.*

nutrition, increased growth rates have often been shown to lead to nitrogen deficiency and a reduction in photosynthetic capacity (Eamus and Jarvis, 1989; Ceulemans and Mousseau, 1994). This reported 'down-regulation' of the photosynthetic apparatus may, however, be a function of experimental conditions, since much of the early work was carried out on potted trees with restricted rooting volumes.

Modelling growth responses to climate change

These complex responses of growth to increasing atmospheric CO_2 and environmental change cannot be modelled using traditional mensuration techniques, since there is minimal spatial variation in ambient CO_2 concentrations. There are data which suggest that site productivity has increased this century (Spiecker *et al.*, 1996), but changes in forest management and many other factors affect the conclusions that can be drawn. Physiological or process-based models can, however, be used to predict the effects of environmental change on forest growth. These models require large numbers of parameters to be obtained from both experiments, such as those described above, and from mature forest stands. The models can then be validated and calibrated with whole canopy water and CO_2 flux data using techniques such as Eddy Correlation, for which an increasing number of sites are available under EU-funded projects such as EUROFLUX and ECOCRAFT.

Interactions between forests and the environment

The interactions which may be of most relevance to forestry are water-use, nutrition and windthrow. Firstly, the predicted combination of increased evapo-transpiration and less rainfall in some areas will mean that water resources may become more scarce. The increased use of water by trees as compared to other forms of natural vegetation could become an argument against increasing woodland and forest cover (UK Environment Agency, 1998). The evidence and predictions are complicated in this area, and although an experimental research programme has been established in the UK, it is too early to draw conclusions. Secondly, 'CO_2 fertilisation' and falling nitrogen deposition may lead to nitrogen deficiencies on some sites, thereby limiting any beneficial effects of environmental change on forest growth. Nitrogen budget studies need to be carried out alongside the modelling activities described above, to identify whether nitrogen deficiencies are likely to become more commonplace in forestry. Finally, elevated CO_2 generally leads to an increase in leaf area, and therefore, to enhanced windthrow susceptibility. This may, however, be counteracted by reduced water availability and nutrition, leading to a change in the balance of allocation to root growth. Predictions of the effects of climate change on susceptibility to wind damage are therefore difficult to make, although suitable windthrow models do exist (Quine *et al.*, 1995).

International agreements and their implications for forestry

Following the Climate Change Convention, the 1997 Kyoto agreement had two important outcomes which influence the position of forestry in climate change response strategies. Firstly, the total agreed decreases of CO_2 emissions were rather small, indicating that the direct effects of elevated CO_2 concentrations, and the secondary effects through climate change, will not be quickly overcome through abatement. Secondly, the idea of increasing carbon sinks, particularly through tree planting, has remained part of the Convention and is included as a possible option in the Kyoto agreement. The sequestration of CO_2 through tree growth therefore remains an important issue, and the quantification of sequestration is currently high on the scientific agenda. There is no doubt that carbon accumulates in the above-ground part of tree crops while they are growing. Whether or not this carbon sequestration is of any long-term benefit depends on the way in which the timber is used after harvest (Matthews *et al.*, 1996).

Forests as carbon sinks

In the UK lowlands, where mineral soils of low organic matter content predominate, carbon accumulates in soil during the growth of a woodland, and there may be a continuous removal of approximately 1.0 t of carbon/ha/yr from the atmosphere. Undisturbed peat accumulates carbon at a rate of approximately 0.7 t/ha/yr, but also emits methane (Cannell and Milne, 1995). The ploughing and drainage of peat for tree planting may, however, result in between 2.0 and 7.0 t/ha/yr loss of carbon. Huge amounts of carbon are stored in peat soils in the UK, with upland peat bogs containing 200 times as much carbon as all UK vegetation (Harrison *et al.*, 1995). It is therefore essential that soil-atmosphere carbon exchange budgets are modelled adequately. It is estimated that European forests remove 85 to 120 million tonnes of carbon from the atmosphere annually (Cannell *et al.*, 1992). This is approximately 5% of the carbon emitted in European fossil fuel burning. About 70-115 million tonnes of this storage results from increased standing volume, and 15 million tonnes from the build up of forest products. The increase in standing volume is primarily because only 70% of the annual increment is harvested. Therefore, standing wood volumes are increasing, although the recently reported enhancement of European forest growth rates may also contribute (Spiecker *et al.*, 1996).

Table 3. *Summary of beneficial and detrimental effects associated with environmental and climate change relating to forestry.*

Factor	*Beneficial effects*	*Detrimental effects*
Resistance to windthrow	Increased allocation to roots in conditions of water or nutrient deficiency.	Increased leaf area and thus, canopy resistance to wind. Increase in occurrence of storm events and mean wind speed.
Water use and availability	Reduced water use as a result of stomatal closure in response to elevated CO_2.	Increased water use as a result of increases in leaf area. Reduced water availability as a result of increases in potential evapo-transpiration and reductions in summer rainfall.
Nutrient availability		Nutrient dilution in response to increased growth. Restriction in availability as soil water content decreases.
Physiology	Budburst accelerated by warmer temperatures. Growing season lengthened by warmer temperatures.	Budburst delayed by unsatisfied chilling requirement. Tissue damage resulting from late spring frosts.
Pathology		Pest populations not reduced during mild winters. Movement of pests and diseases to new regions. Changing disease and pest epidemiology.
Pollution	Reduced acid deposition. Reduced ozone dose as a result of reduced stomatal conductance.	Reductions in sulphur and nitrogen deposition.
Carbon uptake	CO_2 fertilisation effect. Reduced photo-respiration. Increased photosynthesis in response to higher air temperatures.	Increased respiration rates in response to higher temperatures. Reduced carbon uptake in response to summer drought.

Conclusion

These authors cannot subscribe to the idea which has been publicised recently, at least in the UK, that climate change is likely to have an overall beneficial effect in forestry (CCIRG, 1996). This assessment may be an over-simplistic view which cannot be justified by a detailed consideration of the evidence (Table 3). Direct effects of elevated CO_2 are only likely to be beneficial if other environmental requirements are met. Foremost is the availability of water and plant nutrients. The impacts of extreme events and of interactions with entomological and fungal pathogens could also be of major importance and have not been thoroughly investigated. Species and provenance choice may have to be altered, and there is an urgent need for information on which to base such decisions. The provision of suitably scaled predictions of climate and of research into the impacts of these predictions in forestry should continue to be viewed as critical areas of study.

ACKNOWLEDGEMENTS

The work reported was co-funded by the Forestry Commission and the European Commission under the ECOCRAFT programme (ENV4-CT95-0077). The authors would like to thank Janine Hale for her contribution to the work.

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General paper

A glimpse of forestry in Nepal

Bill Stanley[1]

Coillte Research and Development, Newtownmountkennedy, Co. Wicklow.

Paper presented at the Inaugural Sean McBride Memorial Forestry Lecture, 20 November 1996.

Summary

Amidst the devastating impacts of deforestation and environmental degradation, many rural communities in Nepal have adopted an approach to development centred around the principles of community forestry. Community forestry is designed to facilitate local communities to develop sustainable forest management practices which conserve natural resources while ensuring an adequate supply of forest products for the future. This involves the participation of all forest users and potential stakeholders, and the harnessing of local knowledge and indigenous forest management practices. Through the activities of community forestry, many local communities in Nepal have gained the organisational skills, experience and confidence to address broader development needs, such as community health, education and sanitation.

Introduction

Located at a latitude similar to Florida, the kingdom of Nepal is probably best known for its spectacular Himalayan mountains and as the home of the Gurkha soldiers. Probably less well-known, but almost as notable, are the advances which have been made in Nepal in the concept and application of community forestry.

As a country, Nepal is profoundly influenced, both socially and politically, by its two geographical neighbours, India to the south, east and west, and the Tibetan province of China to the north. Nepal is almost exactly twice the size of the Republic of Ireland, with the distance between the northern and southern borders varying between 145-190 km. The country is approximately 900 km from east to west. The elevation of Nepal ranges from 90 m above sea level near the southern border with India, to over 8,800 m at the highest point on the earth, Mount Everest.

There are five distinctive regions in Nepal – the Terai, the Siwaliks, the Middle Hills, the High Hills and the Himalayas – each with its own unique features, culture, flora and fauna. The low plains of the Terai and the most southerly region are very similar to northern India in terms of climate, vegetation and culture. This region accounts for the most productive farmland in Nepal, with 70% of the country's arable land found here. The forests of the Terai are mainly of a tropical deciduous nature, and are mixed with dense stands of elephant grass up to 6.0 m tall. To the north of the Terai are the three hill zones, the Siwaliks, the Middle Hills and the High Hills, each increasing in altitude and hilliness.

[1] Bill Stanley worked for 18 months on a community forestry project in northwest Nepal, with the United Mission to Nepal.

The subtropical wet forests of the Siwaliks and the Middle Hills are mainly made up of broadleaves, bamboo and various rhododendron species. Forest cover in the High Hills includes a temperate mixture of conifers, oaks, bamboo and rhododendron. The mainly uninhabited Himalayas make up the final region, and include eight of the 10 highest peaks in the world.

Monsoon clouds lifting over the terraced Middle Hills region.

Natural forests cover approximately 5.5 million ha or 37% of the total land area. There are over 6,500 flowering plants found in Nepal, including 30 species of rhododendron, the national flower. Most of these flower between February and May, creating a spectacular foreground to the snow-clad Himalayas.

Nepal has a typical monsoon climate, with most rain originating over the Bay of Bengal and generally moving in a north-westerly direction. Eighty percent of the annual precipitation falls between June and September. The Terai receives most of the rainfall as well as the highest temperatures, with both decreasing to the west and with increasing altitude. The amount of rainfall varies significantly with location, but it is not unknown for some regions to experience 1.0 m of rainfall in a single month. This has a devastating effect on an unstable landscape such as that of Nepal. Apart from the threat of physical danger (in 1993, over 5,000 people were killed in Nepal by floods and landslides), estimates of erosion have been as high as 60 m^3/ha of top soil per year.

Principles of community forestry

Over the past 10 years, community forestry has become accepted as one of the keys to successful rural development. Having its origins in the late 1970s, the community forestry movement followed a number of failed attempts to combat deforestation and over-exploitation of local forests in developing countries. These attempts involved vesting ownership of all forest land in the central government, prohibiting unauthorised forestry activities and keeping out local communities and forest users. These moves were based on the conventional wisdom that, if given control, local people would strip the forest bare for profit and survival. In most cases, rather than controlling exploitation, this move resulted in an acceleration of deforestation and general degradation of the forest resource.

Community forestry principles are based on a different conventional wisdom. This is that local people are part of the answer, not the problem, and that forest management policies must involve participation by local people. In many areas of the developing world, forests are used by long-established local communities who have a wealth of local forest knowledge and already practise some form of indigenous forest management. Community forestry seeks to exploit this knowledge to its full potential.

Seeds are planted directly into polythene pots in a community nursery, Jumla.

There are three basic stages involved in the community forestry process. The initial stage is based on the participation of local people in government forestry decisions, subsequently leading to a transfer of control of the forests from the government to the local people, and then ultimately to a stage where the local community manages the forest to meet its needs, processing and marketing any surplus produce. Two of the essential elements of community forestry are: the empowerment of local people through training, extension and technical assistance (this is often the role of an aid agency or a non-governmental organisation (NGO)); and a fundamental change in the role of local government appointed foresters. This change is from a land manager to an extension forester, teacher and facilitator, or, as has been more euphemistically described, from policeman to partner.

Any successful community forestry programme will include a number of essential components. Although these will vary between countries and regions, some of the more fundamental ones are as follows:

An identifiable community and forest area: Straightforward as this may seem, it is not always easy to identify the extent of the local forest-using community. This is especially the case on the fringes of urban areas or in regions where significant migration has taken place. The local forest area can also be difficult to determine, particularly where conflicts of use occur.

Security of land use or tree tenure: In most countries, governments are reluctant to transfer land tenure to local community groups. They are, however, often willing to transfer ownership of the trees and use of the land under certain conditions.

A management plan: This comprises a set of guiding principles and management objectives which will determine the future management of the forest. These are often developed with the local government appointed forestry official, or with the assistance of an NGO, and will be approved by the local government representative before the forest is handed over to the local community. The management plan is usually based on existing indigenous management systems. It is essential that the plan takes into account the requirements of all potential users of the forest, and strikes a balance between any short- and long-term conflicts of interest.

The authority to make and enforce regulations: Authority must be vested in the local community following transfer of the forest area, in order to allow the management plan to be effectively implemented.

A means of monitoring forest management: This is necessary so that serious breaches of the management plan can be corrected.

Commitment from the central government: It is essential that both the local government representative and central government are committed to the programme and are willing to divest themselves of control of forest areas.

All members of the community take responsibility
for the establishment and protection of new plantations.

The application of community forestry in Nepal

There are approximately 5.5 million ha of natural forests in Nepal. These primarily provide basic community needs such as fuel, fodder and bedding for animals, as well as building materials and often basic food supplements and traditional medicines. Due to accessibility and terrain, the Terai region is largely the only region of Nepal with any capacity for commercial wood production. Most of the natural forests are in the hill regions and are being managed by long-established communities. Many communities, however, lack the organisation to effectively conserve this resource, and have no authority to protect it.

Community forestry is a comparatively recent introduction to Nepal. In 1957, all forest land in Nepal was nationalised and brought under government control and protection. Most of this land had previously been under some form of local community management. Rather than protecting the forests, however, nationalisation resulted in an acceleration of deforestation and a general degradation of the overall forest resource. In fact, between 1965 and 1985, almost 600,000 ha of forests disappeared and almost all of the remaining forests suffered severe degradation. In 1989, the government of Nepal adopted a forestry sector master plan which was designed to reduce government control over large forest areas, thereby allowing them to revert to the control of local communities. The corresponding Forest Act, which incorporated many of the community forestry principles, was then passed in 1992. One of the reasons community forestry has worked well in Nepal is that many of the essential ingredients outlined above already exist or are ready to be put in place.

Community forestry in Nepal is based around the establishment of forest user groups. In some cases, these are formed after a significant amount of extension and motivation work, often with the assistance of an external agency or NGO. It is essential that the forest user group includes all forest users within the community, including those normally marginalised due to caste or gender. In Nepal, it is often necessary to structure the forest user group so that women are allowed to have a strong influence, as they are the ones who carry out most forestry activities such as the collection of fodder or firewood.

Once formed, the forest user group is responsible for formulating a management plan for the area of forest which its members commonly use. The areas must be defined in the plan, and areas where there are conflicts of use need to be resolved. This is often one of the most difficult and tricky stages in the process. The local District Forest Office may have input into the development of the plan, but more often, it is largely determined by the forest user group. A typical management plan will include information on where timber can be harvested and during what seasons, the allowable cut, the amount of firewood which can be gathered, areas under total protection, when and where new plantations are planned, etc. When the plan is completed, it is submitted to the local District Forest Officer who can then approve it or suggest and discuss changes.

If the management plan is approved, the forest area in question is handed over to the control of the forest user group. The group will then own the trees but not the land. As well as a transfer of ownership, there is a divestment of authority from the District Forest Office to the group. All forestry activities will then be determined and undertaken by the group in accordance with the management plan.

Although the primary objective of community forestry is to facilitate local communities to address important forestry issues, its ultimate goal is a much more holistic type of rural development. In fact, if community forestry is to be successful, it is essential that other basic community needs, such as water supply, sanitation, community health and education, are also addressed. In many cases, communities which have gone through the community forestry process have gained essential organisational skills, experience and confidence to undertake other projects. Any surplus funds generated from the forest can be reinvested in the community in projects determined by the forest user group. These may include the provision of clean water supplies, soil conservation, building a local school and hiring a teacher, non-formal education programmes, or any other activity which addresses a need that has been identified by the community itself. The role of an NGO in these circumstances is usually to provide technical advice or training. It is essential, however, that the actual issues have been identified by the community.

Women carry out most of the forestry tasks, including fodder and firewood collection.

Conclusion

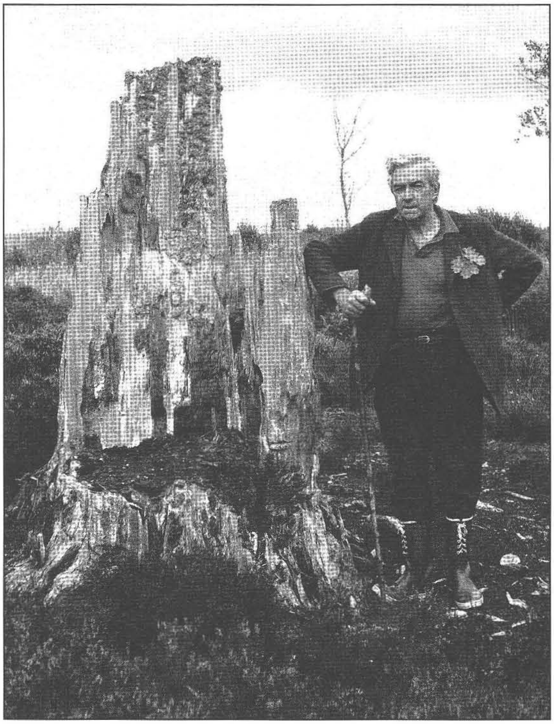
Although the social demands on Irish forests are worlds apart from the needs of the hill communities of Nepal, a number of parallels can be drawn between both countries in terms of the principles and objectives of community forestry. This is all the more so in the context of current efforts in Ireland towards achieving sustainable forest management, and in particular, its approach to forest users and stakeholders.

One of the ironies of such a comparison, however, is the parallel which exists between community forestry practised in the remote areas of the developing world, and its application, under the guise of urban forestry, among urban communities in the western world. The essential ingredients of a motivated community which is geographically defined and aware of how the local forest resource can contribute to well-being of its members, are no less important in inner-city Dublin than in the remote Middle Hills of Nepal.

A clearly outlined management plan which considers all users and potential beneficiaries and which seeks to balance sustainability with ongoing utilisation of the resource, is essential in both scenarios. The commitment of both the community and the local authority to community forestry principles, and the divestment of some level of authority to the community to oversee and implement the plan, are just as valid in Ireland as in Nepal. In addition, the effective application of community forestry can produce the necessary organisational infrastructure which often provides a vehicle for tackling other non-forest related needs and promoting a broader overall development.

There are, however, dangers of extending these parallels too far. While community forestry in Ireland can contribute to the social well-being of a community, in Nepal the practice contributes to actual physical survival. While in both countries the initials stages of community forestry often require considerable extension and education with regards to its potential benefits, few Irish community forestry projects ever generate the level of motivation and commitment of the entire community often secured in Nepal. Out of sheer necessity, whole communities commit considerable amounts of time and resources to ensure success of the programme. The evidence is that community forestry programmes in Ireland can learn much from our Nepali counterparts.

An Appreciation
O.V. Mooney



Owen Mooney died on 22nd February 1999, aged 86 years. Three words in the death notice – "Forester" after his name and "Nature's gentleman" at the foot – summed up the man very accurately. On hearing of the event, one's first reaction may well have been to think that in the Other Place, or wherever else there may be, there would be much handshaking, laughter, banter and then some serious forestry talk.

Owen Vincent (Vic) Mooney was born on 30th June 1912 of a Dublin medical family whose provenance he happily acknowledged to Co. Kildare. Educated at boarding schools in Athlone and Clongowes Wood, he pursued forestry studies at Trinity College Dublin and Oxford University, and qualified from University College Dublin in 1935. His undergraduate training included study periods in France, Germany, Switzerland and Sweden. In taking up forestry, he was following a path pioneered by an elder brother, Dr. Herbert F. Mooney, who had a career in the Indian Forest Service from 1911 to 1947.

He joined the Forest Service (then Forestry Division) of the Department of Lands in 1936, with the infamously titled rank of Temporary Assistant Junior Forestry Inspector, an unestablished post, and served on District management work in Limerick, Mallow, Gort and Clonmel, and as Divisional Inspector in Bray. Following a period as Timber Utilisation Inspector for the Service, he was assigned to lead the newly formed Forest Research Branch in 1957. He retired in 1977 as Assistant Chief Inspector in charge of Forest and Wildlife Research, and Land Acquisition.

As manager, he steered his team with a light rein, motivating people by means of a judicious mixture of advice, encouragement and trust, rather than by heavy-handed direction, a management style which invariably elicited a positive response.

O.V.'s devotion to concentrated desk-work was phenomenal, but one could also recognise his intense satisfaction on getting out into the forest, and his deep interest in and knowledge of everything to be found there.

His contributions to *Irish Forestry* included (*inter alia*) authoritative articles on deer in the forest (1952), lodgepole pine (1957) and eucalypts in Ireland (1960).

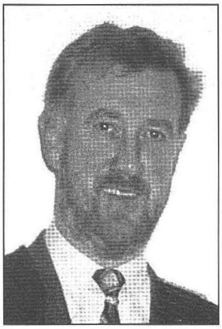
In retirement, he was active as a founder member of the Schizophrenia Association of Ireland.

O.V. Mooney was elected an Honorary Member of the Society of Irish Foresters in 1984, together with Thomas Clear, H.M. FitzPatrick and Sean MacBride. What a company!

Our sympathies are extended to his widow Emma and to his family Brendan, Owen, Ruth, Rosemary and Mary.

Niall OCarroll

An Appreciation
Dick Browne
1950-1998



When reports of Dick Browne's sudden illness circulated through the forestry community on Monday, 10th August, there was a general hope that they had been exaggerated during circulation. This hope was transformed into shock by the sombre appearance of a death notice on Wednesday, 12th August – shock that someone so young and vibrant with passion should be so suddenly taken from our midst.

Dick hailed from Derrybeg, Rosbrien, on the fringe of Limerick City, an area for which he retained a great loyalty and love. It was there that he was laid to rest, in the presence of a vast gathering of family, friends and colleagues.

Dick's forestry career began at Kinnitty 30 years ago in September 1968, when 30 trainees began their studies under the gentle direction of the late John Thornhill. Dick began his career as a forester in Mayo, working at Glenisland, Ballycastle and Crossmolina Forests. He was then posted to Inventory in Letterkenny, remaining there until his appointment to Castlepollard Forest in 1980. He became Region Cost Accountant in the Mullingar Region, and more recently, District Manager in Cavan.

Dick was deeply committed to the Society and was always keen to help out. He was always available to lead forest walks, helped with the staging of Wood Ireland in 1989, and was available when the Society last visited the midlands region at Ravensdale in spring 1997. Early in his career, Dick attended many study tours in Ireland. His coffin was draped with the Society tie – a clear indication of his admiration for the organisation.

He will be sadly missed in the forestry circles, where his death leaves a large void. He will be missed especially by his wife Kay and daughter Claire, to whom we offer our sincere sympathy. We also offer condolences to Dick's parents, Dick and Margaret, his brothers Gerard, Eugene, Kevin and John, his sister Catherine and her husband, John Carmody, Forest Manager, Killane Forest, and to all the members of Kay's family in Wexford. We pray that they will all be given the strength to bear their sad and inestimable loss.

'Ar Dheis láimh Dé go raimh a anam dilis'

John Mc Loughlin

Society of Irish Foresters Annual Study Tour – Finland, 5-12 September 1998

Introduction

On a bright sunny afternoon on 5 September 1998, 45 members of the Society of Irish Foresters set off on a Finnair flight to Helsinki, with a brief stop-over in Stockholm. We arrived in Helsinki late in the evening and were met by Hannu Yli-Kojola, who was to be our guide for the week. Hannu understands the 'Irish ways', having spent the summer of 1980 working at Glenealy Forest. In 1995, Hannu also addressed the Society Symposium in Athlone on Finland's National Inventory (see *Irish Forestry* 53(1&2):55-61). Hannu proved to be an ideal host and guide for the week, looking after all of the group's needs. He also managed to get three newspapers and two radio stations interested in the trip, illustrating the importance of forestry in the life of the Finns.

Finland is approximately five times larger than Ireland and surprisingly is the fifth largest country in Europe. The population is 5 million, with 15.1 persons/km^2. The country is mainly low, flat to rolling plains interspersed with lakes and low hills, with mountains in the north. The main natural resources are timber, copper zinc, iron ore and silver. The main exports are paper, metal, machinery, ships, timber, chemicals, electronics and furniture. Finland exports more paper, paperboard and timber than the USA and Russia combined. Overall, 85% of Finland is covered with trees, and 65% would be classified as high forest.

The success of Finnish forestry, and indeed their entire industrial sector, is the emphasis on quality. When asked how they compete in the ship-building sector with Asia, a Finn replied "we do it right". This is a philosophy we saw in operation at all sites and plants we visited, and for this writer, was the lesson to be learnt from the tour.

I must record my gratitude to Hannu Yli-Kojola for his attention to detail on every aspect of the tour, and to Tom McDonald, who oversaw everything from the Dublin office.

John Mc Loughlin
Convenor

Sunday

Sunday morning brought blue skies and sunshine, ideal for our sightseeing tour around the city with its lovely harbour-side location. Around midday, we set off for Tampere 180 km north of Helsinki, giving us our first view of Finland's vast forest and lake scenery. Mr Hannu Johiluoma, Forest Officer, Senior Advisor, Ministry of Social Affairs and Health, met us on our arrival in Tampere, Finland's second city.

We had dinner in the revolving restaurant at the top of the 168 m high Nasinneula Tower, which offers spectacular views over the city and beyond across the forests and lakes. Following the meal, Mr Johiluoma brought us on a sightseeing tour around Tampere. With a population of 180,000, it is a major industrial city. James Finlayson, a Scotsman, set up a textile factory here. Early evening saw us arrive at Hyytiäla Forest Station, our base for the next two nights and a very pleasant and peaceful setting among the forests and beside a lake. These two nights proved very popular, and many agreed that we could have stayed longer.

Monday

Monday was the first 'official day' of the tour. It began in the classroom, where Dr Antti Uotila, Station Manager, welcomed the group before outlining the station's role. Hyytiäla is the Forestry Field Station of Helsinki University, and was established in 1910 to provide field education in forestry and forest research.

The oldest wooden buildings date from 1910, but further development took place in 1961 when a lecture hall, offices and laboratories were built. Wintertime accommodation and use of Hyytiäla was only made possible in 1977, with the construction of new student hostels and other buildings. Forest students begin their studies in Helsinki before coming to Hyytiäla to undertake practical learning in silviculture, insects, peatland, mensuration and wood technology.

Enough of the classroom! We went on a walkabout around the grounds of the station, where a variety of tree species are growing, and visited the memorial spruce stand. There was a general discussion of Finnish forestry, with the main species being Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and birch (*Betula* spp.). The latter grows to spectacular proportions there. Average rotation for the Norway spruce is about 90 years, with Scots pine slightly less. Moose are the biggest problem with young plantations, and are controlled by culling.

During our visit we saw a clearfell area. Before any cutting takes place, the owner must give a week's notice to cut, and once cut, the area has to be replanted. Adjacent to the site was a memorial stone to forestry students from a class in 1944, who were killed fighting in Russia during the second world war.

A so-called smear station was established in 1995 to record various meteorological measurements. Most of this information is gathered automatically from a 70 m high mast.

Following lunch (dinner!), we went off to visit a local farmer, Mikko Lindel, who warmly welcomed us to his forest with tunes on his accordion beside a fire sending out sweet-smelling woodsmoke. Mikko is a typical Finnish farmer, practising a mix of agriculture and forestry. The revenue from forestry supplements his farming. He availed of grants to assist in establishment, road construction and thinning. Mikko is a member of a local silvicultural society, which provides professional advice for a fee based on 3% of the value of the annual growth.

In the fine autumn sunshine, we went on a most pleasant and interesting forest walk, with stops *en route* to talk about clearfelling, reforestation, fertilisation and training. Like most of Finland, reforestation is carried out using containerised spruce and pine. Natural regeneration is prolific, filling in any gaps. This is very much a family-run business. Mikko and his family operate a healthy farm and forestry enterprise. They have diversified into a small tourism sideline, with several chalets attracting folk to enjoy endless forest- and farm-based leisure activities. At the end of our walk, Mikko's wife had coffee brewing for us over a fire beside a lake. The coffee and 'pulla' bread went down a treat with us all. Wonderful friendly hospitality.

We thoroughly enjoyed our visit to Mikko Lindel's forest, and were greatly impressed by his enthusiasm and love of his farm and forestry enterprise.

On a lovely sunny evening, it was back to the picturesque surroundings of Hyytiäla. The sauna and subsequent swim in the lake was a popular activity. To round off a good day and our stay in Hyytiäla, we all enjoyed an evening meal accompanied by lively musical entertainment provided by a local group. Tour Convenor, John Mc Loughlin, was an excellent MC throughout. A most enjoyable location!!

Richard Jack

Tuesday

On Tuesday, the group departed the Hyytiäla Forest Station and was taken to Lakkasuo, a peatlands area where forest crops have been and continue to be established.

Natural regeneration is a method of establishment practised in this area. Dr Antti Uotila from the Hyytiäla Forest Station directed us to a pine area which was being established using this method. The best trees, Dr Uotila explained, are retained and the seed is dispersed in May. In July, light ribbons are ploughed approximately 15 m apart, to break the surface cover and to aerate the soil. The seed trees, numbering 70-100/ha, are removed after 5 years. The new crop of naturally regenerated seedlings is allowed to grow for 3 years. They are then reduced to 2 m x 2 m spacing by thinning, with spacing increased to 4 m x 4 m after 10 years.

Close to the natural regeneration site, we visited an area of raised bog. The depth of peat was 9 m and the pH ranged from 4-4.5. The area had been drained in recent years, but is still very swampy. The changes in this extensive area resulting from the drainage are being closely monitored. To make this work possible and safe, an elaborate network of rafter paths has been laid down.

The long history of Finnish forestry was actually displayed to us when we were taken to the old growth forests of Susimaki. Here, areas of trees have been growing for over 1,000 years without the human operations of thinning and pruning. Some trees show evidence of fire damage which occurred over 300 years ago. There are areas of birch considered to be in excess of 150 years. Birch forest is thought to be the climax vegetation in Finland, but in the particular area we visited, spruce is thought to be taking over.

In the town of Visuvesi, we visited the Visuvesi Oy sawmill. There, the Managing Director, Mr Pasi Lahtinen, informed us that the mill was established in 1917 by a relation. Today it employs 300 people, and has a turnover of 170 million FIM (IR£22.4 million) and an annual intake of 85,000 m^3. The output is mainly exported, with 85% going to Germany and Britain. The output comprises almost entirely of plywood, and the intake is approximately 50% spruce/pine and 50% birch. Local forests produce 70% of the timber purchased, with the remaining 30% grown by local farmers.

Certification is becoming a fact of sawmilling life all over the European Union. Certification will be swift and easy in Finland. Their long history of strict laws and forest practices will now prove to have been an inspired investment.

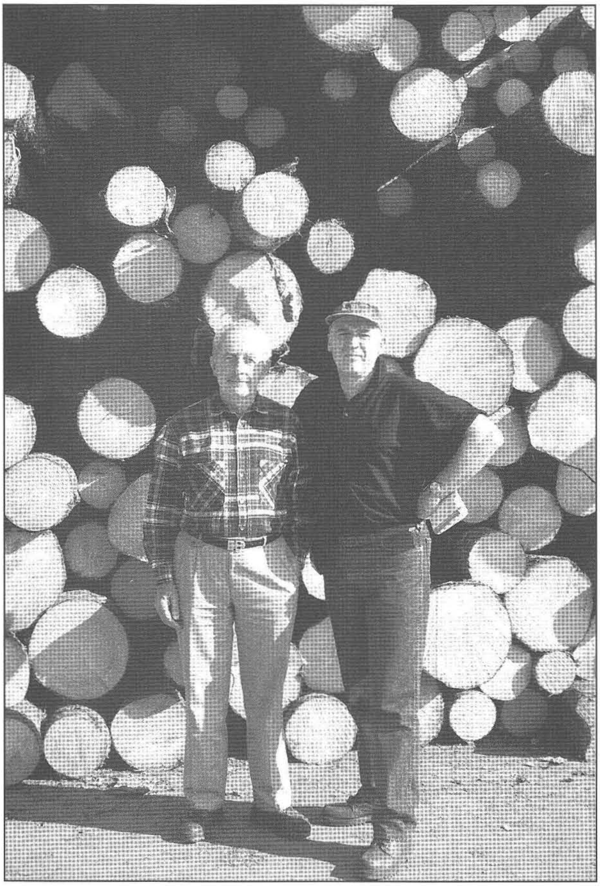
Frank Nugent

Wednesday

On the fifth day of the study tour, we departed Hankasalmi and journeyed 120 km eastwards to the Linnansaari National Park. On arrival at the National Parks Lakeland Visitor Centre, we were welcomed by our host for the day, Mr Tapani Pirinen, Senior Planning Officer, who introduced us to the background and role of the National Parks.

The Forest and Parks Service recognises that there are three major elements in Finnish nature: forest, peatland and water. In Finland, there are 56,012 lakes over 1.0 ha in size. The central lake along the Vuoski waterway is called Lake Saimaa, and is Europe's fourth largest. Seventeen other lakes are connected to it, including Hankivesi, where for the first stop of the day we explored the visitor centre situated on its western shore.

Our guide led us on a tour of the permanent exhibitions. The first portrayed the lush herb-rich forests of the islands in Lake Saimaa. These stands are mainly small in size, covering only a few acres. Despite the small area they occupy, these stands represent one of



Derry O'Hegarty and
Donal Magner
at the Visuvesi Oy sawmill
(Photo: J. Mc Loughlin).

the most diversified living communities in Finland, and are of immense importance to forest biodiversity.

The second theme of the exhibition depicted postglacial life and habitation in the Saimaa area. It included the Saimaa ringed seal and various seagulls which inhabit rocky islets, and the numerous species of duck which thrive on the lakeshores.

The third and last exhibition gave us an insight into the life of early settlers and crofters, who practised slash-and-burn agriculture. This method of existence continued up until the turn of the century. Rye was usually grown first, followed by barley and turnips. A few years after the burn, the area was left to be reforested or, if located close to settlements, to be used as pasture.

Following a coffee break, the group were led to a very impressive auditorium and watched a slide show and audio video on Finland's National Parks. The Forest and Parks Service is responsible for nature conservation work in 32 National Parks, 19 strict Nature Reserves, 53 Herb-rich Reserves, and almost 300 other protected areas.

An important task is the protection of threatened animal and plant species. At the same time, National Parks and their visitor centres offer abundant opportunities for enjoying a wide variety of experiences for recreation.

In Finland, the public has free access to all forests under 'everyman's right'. This is a concept which has evolved in all Nordic countries over the centuries, and is based on an unwritten code of practice born out of the customs and experiences of a sparse population living in a vast, densely forested country.

After the presentation in the auditorium, it was time to head outdoors. Following a short journey from the visitor centre, we boarded the M.V. *Linnansaari* and for the next 45 minutes sailed through an archipelago of islands on Lake Hankivesi (Pike Lake).

Our destination was a crofter holding on an island off the east shore. With a cloudless sky, no wind, temperatures at 20°C and excellent visibility, it was indeed a most enjoyable cruise in the National Parks Lakeland. From an ornithological perspective, it was easy to appreciate how this living lake and its numerous wooded islands hold the highest breeding density of osprey in Europe (14 pairs). Although departed on migration to the south in the last few weeks, one could easily visualise this eagle-like bird of prey hovering above the surface and plunging feet-first for fish in these rich waters.

The group got excellent views of black-throated divers still in their summer breeding plumage, looking much more handsome than when they visit Galway Bay or Strangford Lough to winter on our warmer ice-free shores.

On landing on the crofters island, the group was met by Ms Tiina Linsen, field guide and biologist with the National Park. At our first stop on the island, our host outlined why the area is so important to Finland's natural heritage.

The Saimaa lakeland system is home to Finland's only endemic mammal, the Saimaa ringed seal. Ms Linsen said that this freshwater seal is the most endangered seal in the world, and is on the verge of extinction. The last breeding grounds are located on remote and peaceful islands and islets nearby. The population is threatened by deaths caused mainly by seals getting entangled in fishing nets. She informed the group that, through consultation between the Forest and Parks Service and the local fishing association, net fishing is now prohibited from 15 April to 30 June.

Research has shown that the Saimaa seal can reach an age of 35 years. Approximately 200 individuals survive today, with only 35-40 pups born every year. The Saimaa lake district could, however, provide a home for as many as 2,000 seals without any threat to the fish or fishing. Our guide provided us with a fascinating insight into this rare and endemic mammal, and finished positively by stating that the population is slowly growing. The Forest and Parks Service aims to increase the population to 400-500, through protection and scientific research.

Our next stop was a barbecue lunch beside one of the island's log cabins. A local dish of vendace, one of 38 fish species found in Finland's inland waters, was served up.

During the course of the afternoon, we discovered how Finland's settlers or crofters utilised the forests for food production up to the 18th century. Mr Pirinen was our host for this session. Slash-and-burn cultivation, or swidden cultivation, was the most forest-consuming activity. It involved burning a part of the forest, with the trees ring-barked or cut down, followed by sowing with rye, turnips or oats, or use as pasture. All told, nearly 20% of Finland's forest area has been treated in this manner over the centuries.

During our excursions through the forest, we saw many areas currently managed under this system by National Park staff. These areas preserve the traditions of crofters and the wildlife associated with slash-and-burn cultivation. Mr Pirinen informed us that this particular area holds a species of woodpecker, the white backed woodpecker. They thrived during Finland's slash-and-burn era, but numbers are now falling despite conservation measures.

We arrived at an old crofter dwelling for the final stop of the day. This single-room dwelling was occupied up to the late 1950s by the island's tenants. Access to the residence was difficult, involving a 10 km boat journey in the summer and a journey by horse over the frozen lake in winter. As slash-and-burn agriculture became over-exploited due to a population increase, yields started to decrease. This forest practice gradually became unattractive, and was replaced by timber harvesting and transportation on farms.

After much discussion, it was time for our chairperson for the day, Michael O'Brien, to wind up proceedings. He thanked our hosts and excellent guides Mr Pirinen and Ms Linsen, and presented them with gifts from the Society. This last stop ended a very enjoyable outing to the National Park. We experienced how the people of Finland have lived in, used, changed and protected the forest. We again boarded the M.V. *Linnansaari*, setting off in the warm evening sun for our overnight destination in the town of Savanlinna.

Gerry Murphy
Limerick

Michael O'Brien presenting copies of *Forest Images – Father Browne's Woodland Photographs* to Tiina Linsen and Tapani Pirinen, Linnansaari National Park (Photo: J. Fennessy).

Thursday

The schedule for Thursday was extremely busy and diverse, beginning with an early morning visit to a nursery in Kerimäki, due east of Savonlinna, followed by a visit to the largest wooden church in the world and a drive through some of the beautiful scenery for which this area of Finland - Savo, or Lakelands - is famous. By mid-morning, the tour had reached Punkaharju, home of the Finnish Forest Research Institute and Montell Arboretum. The relentless pace of the morning schedule was maintained throughout the afternoon. This included a visit to Lusto, the Finnish Forestry Museum, also in Punkaharju. Finally, to restore balance amid the strong cultural and research elements of Thursday's itinerary, tour participants visited a harvesting site in Säkilahti before reaching the Päivaränta Centre, Huhtasenkylä, where the group stayed overnight. The chairperson for the day was Liam O'Flanagan.

Kerimäki

The first stop of the day was at a nursery in Kerimäki. The nursery, established in 1992, is one of five in the Itä-Suomen Taimi Group. The Director, Esko Ikaheimonen, told the group that emphasis was on quality production. The nursery has received Certification AAA, which is one of the highest credit rating classifications in Sweden. By the year 2000, it is hoped that the nursery will have both ISO 9002 and ISO 14001. The group has over 200 ha of nurseries. In Syrjälä, there are 35 ha of bare-rooted seedlings, 4 ha of containerised plants and 7,200 m^2 of polythene greenhouses, seven of which are heated. Approximately 45% of the nursery output is bare-rooted plants, with the remaining 55% as containerised stock. According to Esko Ikaheimonen, Nursery Director, the trend is to produce mainly containerised plants within a few years. This gives more control over quality production, and provides customers with an opportunity to extend the planting season. In addition, due to the short growing season and cold climate, vegetation competition is not a problem in most of Finland's forests, again prompting the increased emphasis on containerised stock. The trend towards containerised plants has already been established, as virtually all plants now used in State forest establishment and most private forests are containerised. Syrjälä Nursery, which is small by Finnish standards, produces the following species:

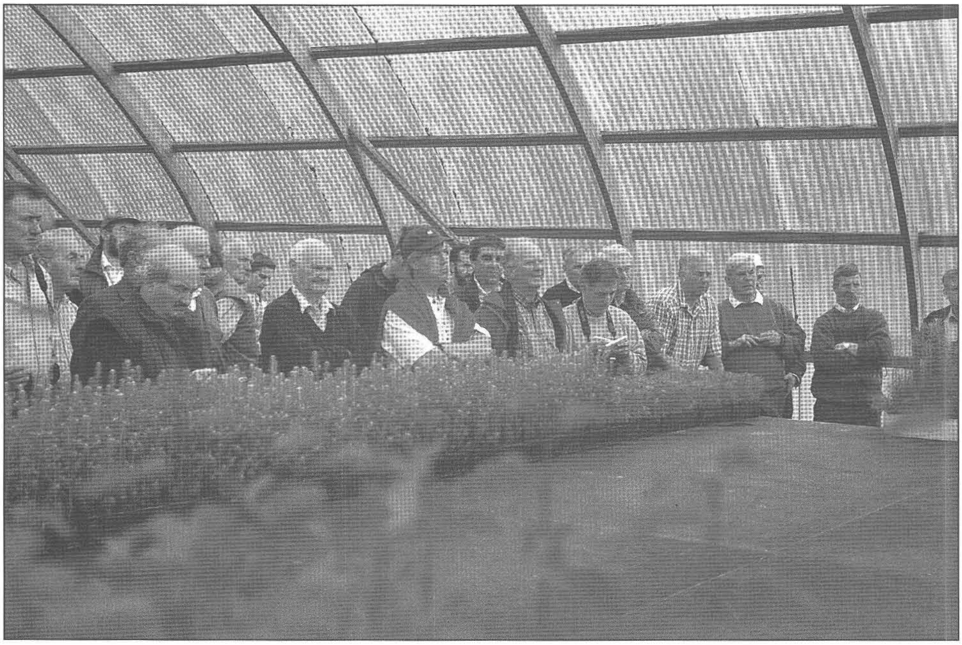
- 350,000 Scots pine (80% containerised);
- 1,100,000 birch (45% containerised);
- 2,100,000 Norway spruce (52% containerised);
- 110,000 larch (*Larix* spp.) and others (100% bare-rooted).

Total turnover is 5.4 million FIM (IR£0.7 million). Most of the plants (86%) are purchased by management associations who act as agents for private landowners. Eleven full-time staff and up to 40 seasonal workers are employed in the nursery.

A trip to Kerimäki would not be complete without a visit to its famous wooden church, Kerimäen Seurakunta. It is the largest wooden church in the world, and has a seating capacity of 3,300. It seems that the church was never intended to be designed on such a large scale by the architect, A.F. Gransdedt. However, the local builder master, Axel Topola, took advantage of flexible planning laws and, urged on by megalomaniac parishioners, changed feet to metres on the plan, creating an impressive edifice which dominates Kerimäki.

Punkaharju Research Station and the Montell Arboretum

At Punkaharju Research Station, a tour was organised by Dr Juhani Häggman, Finnish Forest Research Institute, Metla. The institute was founded in 1918 and is proudly celebrating 80 years of research. Dr Häggman provided the group with a fascinating history of the region's forests, which owe a debt of gratitude to Czar Alexandra. During one of his sojourns from St. Petersburg, the czar noticed that the area - then part of Russia - had poor forest cover. This had resulted from over-exploitation by farmers. In 1803, he ordered the protection of the forests. Some 40 years later, the Imperial Senate decided to establish a Crown Forest Park in Punkaharju.



Society group at the Syrjälä Nursery, Kerimäki (Photo: J. Mc Loughlin).

Since the 1920s, research at the centre has been specialising on genetic studies and, in recent years, the effects of greenhouse gasses. In Punkaharju, 34 permanent staff are employed along with 50 seasonal and visiting temporary staff. Studies currently being carried out include adaptation of forest trees to climatic change, cultivation research on introduced species, micropropagation and resistance breeding.

The nearby Montell Arboretum, established by Robert Montell in 1877, has an impressive array of native and introduced species. While it is only possible to mention a fraction of the species grown here, a number make an impact. Siberian spruce (*P. obovata* Ledeb.) is extremely impressive and seems to be capable of adapting to a wide range of soil types and climates. It is one of the few non-native species in which Finnish foresters see some potential, although it is likely that the trend of planting indigenous species will continue. A stand of European larch (*L. decidua* Mill.) established in the 1880s has a top height of 44 m. Other larches performing well are Dahurian larch (*L. gmelinii* (Rupr.) Kuzeneva) and Siberian larch (*L. sibirica* Ledeb.). The arboretum has a comprehensive range of pines, including Arolla pine (*P. cembra* L.), lodgepole pine (*P. contorta* var. *latifolia* Wats.), Macedonian pine (*P. peuce* Griseb.) and of course, Scots pine. The group was surprised to hear that the less than impressive curly birch stand was the most valuable in the arboretum. These poorly-formed and slow growing trees are capable of achieving prices of 35,000 FIM (IR£4,600)/m^3, due to their highly prized distinctive grain.

Lusto – the Finnish Forestry Museum and Forest Information Centre Punkaharju

Lusto, which means 'annual ring', is an ideal way to educate the public about forestry and to illustrate the silvicultural, productive, economic, social, cultural and historical layers of this multifaceted industry. While we do not possess the same range of material and memorabilia to construct a museum of this scale in Ireland, this writer believes that we do have the venue (Avondale) and the expertise to recreate much of our forestry heritage in exhibition form. Perhaps we should aim to establish early in the millennium a museum in Avondale, to celebrate its 100-year anniversary as a forestry training centre.

The museum illustrates the commercial life of the forestry industry in Finland alongside the rich heritage of the forest. There are art and educational exhibitions aimed at school children, and displays of forest tools and equipment along with traditional forest industries and crafts. During our visit, there was a fascinating exhibition of woodcuts by the Finnish artist, Tapio Kelo-Puomia, who began life as a forester.

Harvesting in Säkilahti

The final stop of the day was at the forest of Säkilahti, where the group saw Finnish technology at its best in a harvesting site. The forest, owned by the multinational timber and pulp production company, Enso, was being harvested at a rate of 250 m^3/8-hour shift and removed to roadside at a cost of 60 FIM (IR£8)/m^3. Enso has over 600,000 ha of forests. There is very little manual harvesting in their forests. This is reflected in employment figures throughout the industry. The forestry and forest products sectors currently employ 97,000 people, compared with 183,000 in 1980. After the Soviet collapse, the Finns developed highly automated industries which did wonders for their economy, but little for employment. Since 1980, despite almost halving the number employed in forestry, production has increased by 30%.

After a week of unexpected warmth and sunshine (like Ireland, Finland experiences a very wet summer), it began to rain as we made our way to the Päivaränta Centre, Huhtasenkylä. Despite this, the group availed of the barbecue facilities and the lakeside sauna only a few miles from the Russian border. Late in the evening, the barbecue revellers gazed across the lake at the silhouettes of the massive funnels belching out smoke from the pulpmills of Imatra. In a few short hours, they would say *näkemiin* to the beautiful region of Savo and *hei* to polluted Imatra and despondent Russia.

Donal Magner

Friday

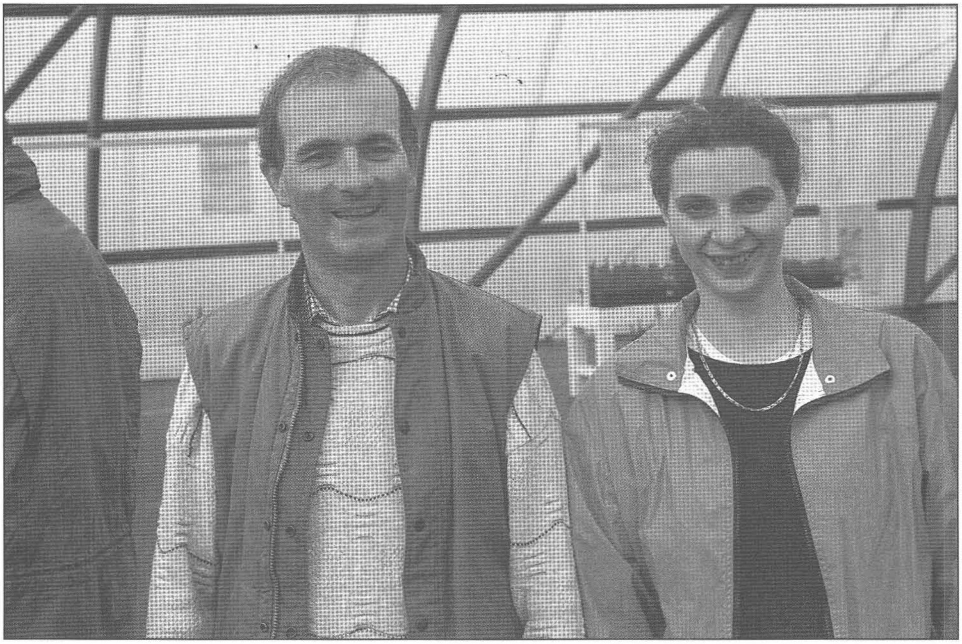
Following a pleasant overnight stop at the Päivaränta Centre, we departed to visit the Enso pulp and paper factory at Kaukopaa, Imatra.

Enso has two plants at Kaukopaa and Tainionkaski, both of which are located in Imatra (population 32,000) on the shore of Lake Saimaa. The Imatra mills belong to one of Europe's largest forest industry groups, Enso Oy. Enso is a leading manufacturer of fine papers, publication and packaging boards. The product range also includes pulp, sawn goods, coreboards and laminated papers.

The group boasts an impressive array of statistics: it produces 6.7 million tonnes of paper and board annually; sawmilling capacity is 2 million m^3; wood raw material consumption is 25 million m^3; sales in 1997 were 29.3 billion FIM (IR£3.9 billion), 85% of which is accounted for by exports and foreign operations; 20,000 personnel are employed world-wide. Shortly, they are to amalgamate with Stora, the Swedish forestry company.

Enso's Imatra mills employ 2,500 people, and production capacity is 1.1 million tonnes/year of paper and paperboard. Wood raw material consumption is 3.5 million m^3/year.

Upon arrival, we were afforded a cordial welcome by our guide, Mr Martii Savolainen,



Pat O'Sullivan and Patricia Flanagan (Photo: J. Mc Loughlin).

a forester by profession and now PR Manager for the Imatra mills. The visit commenced with a tour of the active sludge treatment plants installed at a cost of 200 million FIM (IR£26.3 million). Advanced technology is employed to treat discharges from the production processes. Pulp mill water is treated biologically, and boardmill water chemically. Approximately 200,000 m^3 of water is treated every day, with a treatment cycle of 30 hours. The resulting sludges are burned along with the bark to produce energy.

About 50% of the wood arrives at the yard by rail, 45% by road and the rest by water. Overhead cranes with 8-10 m^3 grab capacity can unload 450 m^3/hour, or approximately 10 truck loads/hour. A total of 7,000 m^3 of logs are unloaded daily over two shifts, and a 2-week supply (135,000 m^3) is stored in the yard at all times. Following unloading and storage, the logs are fed into debarking drums and the wood is then converted into chips. The wood chips are fed into digesters and heated to remove the lignin. The resulting fibre is washed, bleached and pumped to the paper and board machines for conversion.

To achieve the desired characteristics for the paper and board, the pulp fibres are beaten in refiners, and the necessary chemicals are added. The pulp slurry is fed to the head boxes of the paper and board machines. The dilute pulp slurry is forced out of the head boxes and onto the wire, where web formation and dewatering take place. Dewatering continues in the press section, and the web is finally dried in the dryers. Overall production capacities are 800,000 tonnes of board/year and 400,000 tonnes of paper/year.

Imatra's paper and board machines were developed and installed by Valmet. Board machines employ multilayer technologies. Liquid and food packaging boards are coated with polythene. Graphic and packaging boards are mineral-coated before being cut into rolls or sheets, depending on customer requirements. The main converted paper product is A4 size copier paper.

The ISO 9000 standard has been in force in all production units since 1992, and ISO 14001 has been integrated into the quality system to meet the target of Enso's environmental policy of living in harmony with nature.

The awesome size of the various plants and equipment, the scale of production capacities and the level of advanced technologies employed to ensure both process and quality control, were most impressive. The Imatra mills bear testimony that the Enso Group will indeed have no difficulty in achieving its ultimate aim to rank permanently among the world's top three suppliers of paper and board.

In his concluding remarks, the Chairperson paid tribute to Enso for facilitating the Society's visit, and for the quality and array of information literature provided to the members. He paid special tribute to Mr Savolainen for his time and hospitality afforded to the group, in particular, his ability to bring us through the entire paper and paperboard manufacturing processes in an easy, informative manner.

Following the waterways linking Lake Saimaa to the Baltic seaport of Vyborg, formerly Viipuri, we travelled south to cross the Russian border at Nuijamaa. Entering the Russian Federation involved a tiresome process of checkpoints before finally reaching the Passport and Customs Control Centre. At this centre, staff and facilities were not customer-orientated. Neither are they adequate to cater for the large volume of tourist and commercial traffic. Long delays associated with the various levels of officialdom are normal. We eventually managed to get through the checkpoints without a hitch, boarded our bus and diverted our attentions again to forestry issues.

The extensive forests viewed were very similar in terms of species content and age structure to those visited in Finland. The notable difference was that birch was the dominant species. Also, forests had not been managed since the lands were ceded to Russia in 1944. As a result, log sizes were significantly reduced.

We heard so much about the presence of moose in the forests throughout the tour, and despite the continuous stream of warning and hazard signs along the roadways, we failed to make any sightings. Much to the delight of all, we finally sighted a moose crossing the roadway near the Nuijamaa border post.

On reaching Viipuri, our first stop was at the market square for lunch in the medieval banquet rooms located in a roundtower built during the Swedish occupation. Following a pleasant lunch, we proceeded on a tour of this once prosperous and cosmopolitan city, when its population was a mixture of Finns, Swedes, Russians and Germans. With many of its architecturally acclaimed buildings, squares and parks still in existence, Viipuri has a strange time-locked quality. Sadly, both the old neo-classical structures and the newer apartment blocks constructed during Soviet era have reached advanced states of dilapidation. It appears that old Viipuri and its elegance reminiscent of pre-war Finland could well be razed to the ground, with post-Soviet entrepreneurs appearing on the scene.

The plight of the city's inhabitants was equally distressing. The current period of economic and political unrest has increased the levels of petty crime and muggings. Many people were reduced to begging and selling trinkets in the markets. Mindful of our money, passports and possessions, group shopping in the markets was strongly advised. With safety in numbers, shopping was an experience as the vendors were friendly and eager to exchange items, such as Soviet memorabilia and crystal and wooden products, for hard currencies, particularly US dollars. Our shopping sojourn was brisk and hurried. Our driver, mindful of the delays expected at the border, was anxious to commence our long return journey to Helsinki.

Leaving the market *via* the prominent Swedish castle overlooking the port, we travelled along the major commercial highway (E 18) connecting Russia to the west. We departed Russia at the border checkpoint of Valiniaa, with a delay of 45 minutes. Here, staff and facilities were adequately geared to handle the flow of commercial and tourist traffic. On leaving Valiniaa, we journeyed for 190 km to Helsinki, passing through a mixed landscape of forest and open farmland, reaching our destination, Hotel Helka, at 9 pm.

The tour concluded with an informal dinner at our hotel. Our special guests included members of the Finnish Society of Foresters. In welcoming the guests, our President, John Fennessy, paid tribute to the tradition and level of forestry professionalism in Finland, wherein their astute environmental and commercial management practices have ranked Finland among the world's leading suppliers of wood and paper products. He commented on how successful the tour had been and paid compliments to all involved in its organisation, with specific thanks to John Mc Loughlin, Tom McDonald and our driver, Jakli. Finally, he made special reference to Hannu Yli-Kojola. Hannu, as our guide for the week, worked tremendously hard to organise the itinerary and to ensure that the programme ran smoothly and most efficiently. In conclusion, Joe Treacy, speaking on behalf of the tour participants, paid tribute to the organisers for the success of the tour.

Eamon Larkin

Tour participants

Collins, T.
Crowley, J.
Dooley, J.
Doyle, J.
Drea, P.
Ellis, K.
Farmer, C.
Fennessy, J., President
Flanagan, P.
Fleming, J.
Flynn, B.
Gallinagh, T.
Gault, J.
Griffin, R.
Hipwell, G.
Howe, L.
Hunt, T.
Jack, R.
Jones, S.
Lacey, B.
Larkin, E.
Magner, D.
Mannion, T.
McCloskey, P.
McDonald, T.
McDonald, K.
McEwen, J.
Mc Loughlin, J., Convenor
Monaghan, B.
Murphy, L.
Murphy, G.
Neilan, J.
Nugent, F.
O'Brien, M.
O'Flanagan, L.
O'Hegarty, D.
O'Neachtain, M.
O'Neill, B.
O'Regan, T.
O'Sullivan, P.
Patterson, G.
Purcell, T.
Treacy, J.
Whelan, R.
Wilson, T.

(Photo: J. McEwen)

Letters to the Editor

Dear Editor,

I joined the NI Forest Service in October 1954. During my time, I have seen trees grow to produce fine crops on good dry soil, but fall down on the shallow soils, due to the wet ground conditions and the lack of rooting depth.

During my time in Harvesting, I noticed that the start of 'windthrow' could usually be traced back to blocked drains in contour ploughing or turfing. Also, the necessity to cross cut-off main drains to extract timber during thinning operations caused irreparable damage to the remaining crop, often leading to windthrow.

From this I deduced that we should be trying to dry the ground to provide a deeper rooting medium for our tree crops. This can only be done by lowering the water table, and in the long-term, giving our trees access to more nutrients in the subsoil, which are often present in abundance but unavailable, due to the shallow water table.

To attempt to dry the ground, we must put in deep drains. To avoid foreseeable problems, such as the above difficulty during extraction, these drains must run up or down the slope to give unimpeded access across the site. I am advocating that these drains should be put in at least 1 m deep and between 16-18 m apart.

Regardless of the lie of the ground, if we are to put in 1 m deep drains at 16 m spacing, we are immediately creating a fall of 1 in 8 from the center of the area between drains to the drain bottom. In the long term, this lowering of the water table will cause a change in the whole structure of the soil, and more importantly, the subsoil.

Another benefit of these deep drains is that they should never need any maintenance and will probably be adequate for at least two rotations of timber crops. Through natural climatic conditions, the edges of the drains will dry out, stones and grit will fall out of the drain edge, and the bottom of the drains will be colonised with grasses, etc., until the tree canopy is formed and light excluded, although whether this is desirable is debatable.

A third and perhaps the greatest benefit is the fact that there should never be as great a run-off after heavy rainfall as is sometimes created by contour drains catching surface water and speeding it to main drains and streams, thus avoiding rapid erosion and the contamination of rivers and lakes. In the situation that I am envisaging, the area would act as a natural sponge, and heavy rainfall would gradually soak into the main drains over two or three days, rather than two or three hours, as is currently often the case.

It is my considered opinion that any investment in drainage, like that in roading, is an investment in the land, and should not be charged solely against the first crop produced. If our forefathers on this island had not dug ditches and drained their fields, we would not have inherited all the good land we have today. If we are to grow trees on marginal land, it is up to us to improve the whole soil structure and depth, so as to enable it to support crops of trees for future generations. Too often when windthrow occurs, we hear the excuse being made that we are subjected to severe gales off the Atlantic. Yet, if we go to these sites, we very often find trees growing quite happily on the skyline. An examination of these will often show that they are standing on an old field ditch, with a good depth of soil for anchorage.

When transferred to Antrim Harvesting in 1982, I found myself having to fell second rotation crops in Ballycastle and Tardree Forests which I had seen planted in the early 1960s. I convinced the late Jim Caithness that we should be using a digger to introduce deep drainage to improve ground conditions. This was done in a very irregular pattern which will make the area difficult to manage as far as harvesting is concerned, but the improvement in ground conditions has led to some fantastic growth. One particular tree which I have marked in Tardree Compartment 38 P84 measured 12 m tall, with a dbh of 18 cm, at 12 years of age.

When transferred to Slemish in 1990, I laid out the P91 and P92 areas of Woodburn in Compartments 18, 42 and 43. Drains and mounds were spaced at 17 m and 2 m respectively, running up and down the slope to and from the road, to allow unimpeded access for extraction in future years, and hopefully, greater stability. Both of these areas had old watercourses running diagonally across the sites, together with old field ditches which I completely ignored by putting in the new drainage system deep enough to cut them off. To date, there has been nothing exceptional about the growth on these sites. The factors described above, however, have occurred, i.e. stones and grasses in the bottom of the drains, general 'falling-in' and shrinkage of the drain sides, and no rapid run-off after heavy rainfall.

Unfortunately I may not be around to see the final results of this work. I have, however, been granted permission by the Chief Forest Officer in the NI Forest Service to have these areas recorded as the Toppings Trials, and have written this article as an explanation of my vision of how forests must be established.

Yours etc.,

F.I. Topping

Dear Sir,

Among the assortment of books in a rural hotel in west Connaught is a copy of *Thom's Official Directory 1920*. Idle browsing discovered the following entry (page 1057) among a list of Principal Irish Societies and Institutions:

> Irish Forestry Society (1902)
> President – Marquess of Headfort
> Hon. Secretary – J. Scott Kerr, Cloneen, Tubber, county Clare.
> Secretary – E. Knowldin, F.R.H.S., 5 Molesworth-street, Dublin.
> Hon. Treasurer – O.H. Bradell, L.S.O., Lower Bullingate, co. Wicklow.
> Objects. – (a) The advancement in Ireland of Scientific and Practical Forestry in all its branches; (b) the dissemination of a knowledge of such branches of Science and Arts as are connected with Forestry; and (c) the diffusion of information as to the benefits to be derived by the nation (collectively and individually) by the Science of Arboriculture properly understood and applied.

The Society gave evidence to the 1907 Departmental Committee on Irish Forestry, as recorded in the Minutes of Evidence and Appendices subsequently published.

I suggest that the Society deserves further research to elucidate its initiation, its activities and achievements, its demise and a list of its more eminent members. Perhaps one of our academic bodies might consider recognising the results of such research.

Further browsing in the Directory leads us to a "List of the Nobility, Gentry, Merchants and Traders" in Dublin, which includes: "Henry, Augustine, 5 Sandford terrace, Sandford road, Ranelagh", but no A.C. Forbes. However, in "Officers of Government and Public Departments etc." we find "Forbes, Capt. A.C., Chief Forestry Inspector, Dept. of Agriculture." Perhaps the distinction reflects the perceived social difference between an academic and a civil servant. But whence the captaincy?

Yours sincerely,

Niall OCarroll,
Ballynakillew,
Ballinrobe,
Co. Mayo.

(Editor's note: Letters to the Editor on all aspects of forestry, both current and historical, will be welcomed for publication in future issues of Irish Forestry.*)*

Book Reviews

Heterobasidion annosum: Biology, Ecology, Impact and Control

Edited by S. Woodward, J. Stenlid, R. Karjalainen and A. Hüttermann. 1998. CAB International, Wallingford, Oxon OX10 8DE, UK. ISBN 0-85199-275-7. 589 pages. Stg£75.

Reviewed by Dr Kevin Clancy, Plant Pathologist, Department of Environmental Resource Management, University College Dublin.

Heterobasidion annosum*: Biology, Ecology, Impact and Control* addresses, very successfully, the mammoth task of interpreting and integrating the vast literature on the most important disease of conifers of northern temperate regions. With the experience and expertise of the contributors, the publication represents an invaluable source for people involved in any capacity with *Heterobasidion annosum*. It was produced with grant support from the European Union, and represents excellent value for money for the funding agencies and for anyone who purchases it. The content of this book could easily have been extended over a number of volumes. Careful and precise writing and edited have, however, condensed it into a focused publication which really needs careful reading and rereading to ensure that one does not miss some of the finer points, which are all presented, but not laboured.

It is a thoroughly useful and up-to-date work which takes us through many aspects of the pathogen and the resulting disease, from symptomatology and associated host-pathogen interactions (both physical and biochemical), through the biology and epidemiology and into an excellent control section which will be welcomed by those primarily concerned with disease management. The taxonomic treatment acknowledges the older name *Fomes annosus*, which many people still insist on using, and all the associated taxonomic niches. It quickly moves on to the current situation, as is found with many pathogens today, where not only do we need to accept and use the correct name *Heterobasidion annosum*, but also to appreciate the diversity within the genus and more particularly, within the species. It can now be separated into up to five recognised intersterility groups, many of which are now themselves worthy of being considered as new species. In that context, there are excellent chapters on the diagnosis, differentiation and distribution of the different intersterility groups. These chapters even include useful and usable methodology which one rarely finds in an all-encompassing publication on any disease.

With over 2,000 references, this book will be an essential resource for anyone involved in research or teaching. The control chapters and appendices, ranging from the chemical and biological options to the silvicultural and host resistance options, even including the relatively recent SAR concept. The disease modelling and cost-benefit chapters present us with a thorough assimilation of the state of current knowledge and practice. One needs to look no further!

From the Irish perspective, though we have relatively little local work on which to draw, the reports from European and North American regions on the impact and occurrence of the problem and the current management practices, will reassure us as to our current approaches to managing this major pathogen.

My only real criticism has to be in relation to the presentation and colour tone of the colour photographs. There were probably some practical and economic reasons for clustering the plates into eight pages, but all, except the photomicrographs and diagrams, would have really benefited from a more enlarged presentation and positions adjacent to their relevant chapters.

Notwithstanding this slight reservation, the book will be indispensable to many for as long as they have an interest in any aspect of *Heterobasidion annosum*. The originators of the idea and the contributors and editors can all be proud of their work.

Policy Paper on Forestry and the National Heritage

The Heritage Council, Kilkenny, Ireland. 1999. ISBN 1-901137-08-2. 64 pages. IR£7.00.

Reviewed by Patrick Purser.

This policy paper on forestry and the national heritage should be read by all foresters currently practising in Ireland. It is only on reading it that the enormity of the task of trust-building between the forestry profession and others becomes apparent. It is obvious from this document that the Heritage Council has little trust in the forestry profession. Its authors may be surprised to learn that, probably without exception, foresters regard themselves as lovers of the countryside, as custodians of our national heritage, as upholders of all that is best in rural development, and as a profession doing something positive for both the environment and rural socio-economics. But somehow, if this policy paper is anything to go by, we have convinced nobody of this. The forestry profession, as such, is not mentioned once in the document.

First impressions are that the Heritage Council seems deeply dissatisfied with current forestry policy. If we can swallow our pride and be open-minded as we read the document, we will, however, discover that much of what is recommended is currently observed by practising foresters and is actually happening on the ground. Indeed, this is one fault with the document. Too often, it criticises forestry practices which are already history. Due to the long-term nature of forestry, many of today's criticisms are manifestations of past policies. The Heritage Council makes no recognition of this.

There appears to be no regard anywhere in the document for economics. This needs to be addressed by the Heritage Council in a follow-up document. What will be the economic effect of the adoption of their recommendations? It would seem clear that, if all the recommendations were to be followed, the commercial mandate currently given to Irish foresters would have to be removed in favour of a socio-environmental one. Given that most of the current forestry developments are being carried out by farmers, and are set to continue as such, the Heritage Council must cost their proposals and identify where the funds for their implementation are to be found.

Many of the recommendations in the policy paper seem to have little technical basis.

Due to the lack of supporting references, there is an impression that many of these are borne out of 'gut feelings' rather than any objective research. There is frequent reference to the need for balance in forestry policy between such things as biological diversity and commercial objectives, coniferous and broadleaf species, etc. One wonders if the recommendation "that Ireland's forestry policy adopt a strategic planting target of 1:1 broadleaved species to conifer species" is based on an assessment of suitable and available sites, or simply out of a sense of fairness to competing interests.

It would be wrong, however, to continue this review in a negative manner. The policy paper is an honest and, in many places, enterprising document which clearly outlines the Heritage Council's position on forestry. There are many recommendations to be welcomed, particularly in the area of broadleaf management. These include: "that Ireland's forestry policy should encourage use of local Irish seed"; "that substantial research and education effort be directed at developing broadleaved tree management and silvicultural skills amongst forestry owners"; and "that a complete inventory of the remaining areas of semi-natural woodland in Ireland is undertaken, and their active management and conservation is promoted". There is also a call for the abolishment of the requirement to replant as a pre-condition for a felling licence, and for greater liaison between forestry bodies and other interests, such as archaeologists, ecologists and County Councils.

To date, foresters have been defensive rather than inclusive about their contribution to rural Ireland. Our involvement has been positive, but we will continue to convince nobody of this unless we allow other interests to share in the planning and implementation of forestry developments. Now is the time for trustful and open-minded communication to commence between foresters and other professions and interests, starting with the Heritage Council.

Ireland – A Natural History

David Cabot. 1999. Harper Collins Publishers. ISBN 000-220080-5. 512 pages. Paperback. Stg£17.99.

Reviewed by Declan Little, Co-ordinator of the Woodlands of Ireland Millennium Project.

After exploring David Cabot's comprehensive volume on Ireland's natural history, it is clear that the style lends itself as much to the casual reader with a passing interest in the environment as it does to the specialist in any of the fields covered. The author's considerable experience in the biological field, which spans almost 40 years, is translated impressively with the help of an array of specialists from a variety of backgrounds. This book, like Mitchell and Ryan's *Reading the Irish Landscape*, bridges the gap between the scientific arena and the general public, but in addition, Cabot describes each of Ireland's habitats in considerable detail.

The opening chapter on the history of naturalists and their work in Ireland chronologically describes the contributions of clerics, scholars and travellers since early Christian times. This is colourfully described through a mixture of poetry, prose and superstition. Some humorous anecdotes are imparted, including a number attributed to Giraldus Cambrensis, grandson of Henry I. In 1188, he noted in his infamous *Topographia Hiberniae*, "barnacle geese hatching from goose barnacles found clinging to floating logs in the sea." According to Cabot, "such miracles were in vogue, a convenient way of explaining mysterious phenomena and the substance of bestiaries." The many interesting historical observations described include one by William Hamilton Maxwell in his vivid *Wild Sports of the West, with Legendary Tales and Local Sketches* (1832), where it is recorded that some of the last indigenous red deer of Mayo were persecuted almost to extinction during his time with the aid of muskets abandoned by the French in 1798.

This chapter is followed by a biological history of Ireland, beginning approximately two million years ago. Geology, paleobotany, climate, flora and fauna are intricately woven into a distinctive style interspersed with some controversial conundrums which have puzzled specialists in the botanical and zoological fields alike. How Ireland acquired its flora and fauna is given special attention, with the author finally postulating that both arrived here though a combination of migration from Britain and southern Europe, by aerial dispersion, chance methods and introductions by early man, and lastly, through the survival of preglacial colonists in ice-free areas. This chapter sets the tone for the following nine chapters, which deal exclusively with Ireland's main habitat types: mountains and uplands; peatlands; lakes and rivers; the Burren and turloughs; broadleaf woodlands; farmland; the coastline; islands; and the sea.

At times, the sheer volume of detail and the use of Latin nomenclature interrupt the author's appealing narrative flow, but this does not discount from what can only be described as a most wide-ranging and current description of Ireland's many and sometimes unique habitats. Some will not like the author's tone in the opening paragraphs in the chapter on broadleaf woodland, where an account is given of "a man-induced devastation of a once vast and thriving ecosystem, reduced today to a mere vestige of what it used to be" and succeeded by "recent coniferous plantations dominated by two species originating from the Pacific coasts of British Columbia and southern Alaska – sitka spruce and lodgepole pine – sprawling like advancing armies across the landscape" and "despised by most naturalists as 'ecological deserts'."

Such statements are a preamble to the final chapter, which concerns the conservation of nature. Set against the extinction of many species of flora and fauna, either through habitat destruction or direct persecution, the author suggests that "a nature conservation strategy for Ireland should aim to protect a representative range of the best habitats from mountain summits to the sea bed, as well as particular species requiring safeguarding." Not everyone will agree with the author's views on man's interaction with nature, which appears to be derived solely from the conservationist perspective.

This book is a descriptive, factual tapestry of Ireland's natural history, interspersed with history, anecdotes, data and a number of exquisite photographs. It is, at the very least, a reference for anyone who wishes to explore Ireland's array of terrestrial and aquatic habitats, with particular emphasis on its unique habitats, especially its wildfowl refuges and the Burren in Co. Clare. It outlines the principal threats to Ireland's natural heritage and the challenges which face us all as we enter a new millennium. The book does contain a number of small grammatical, spelling and technical errors. These do not, however, take away from the flowing narrative style, and could be easily remedied in the next edition. In the final analysis, *Ireland – A Natural History* should stand the test of time.

Trees, Woods and Literature – 23
Describing Giant Trees

Today, a tree is likely to be described by a Latin name and a series of numbers representing its grid reference, girth, height and crown spread. Although useful, this pared-down approach gives little impression of the true magnificence of a mature tree. Perhaps we could interest more people in trees by using some of the almost mythical language of earlier writers. After reading the following descriptions, who wouldn't want to visit these three giants, climb inside the Doniry Ash, sail a boat made from the Portmore Oak, or assemble 72 horses under Ballygamboon's apple tree.

It would be unpardonable not to mention the Doniry ash, on the road between Loughrea and Portumna. When I saw it in 1803, it was in a state of great decay. It was so large, that I was informed a weaver worked at his loom in it, and his family lived with him in it. It was surrounded with iron hoops, which I hope have preserved it. When Mr Hardy saw it some years since, it measured at four feet from the ground, 42 feet in circumference; at six feet high, 33 feet round. About 25 years before Mr Hardy measured it, a school had been kept in it.

An ash tree in Co. Galway, described by Hely Dutton (1824; pp. 442-443)

The Great Oak of Portmore was blown down about 1760. To the first branch from the ground was 25 feet, and the circumference measured 14 yards! A single branch was sold for £9; the stem for £97; and the principal part of the remainder, bought for £30, built a lighter[1] *of 40 tons' burthen. Many articles of furniture were made of it, and are held still in great estimation.*

[1] a type of barge

An oak at Portmore, Co. Antrim, described by Hume (1853; pp. 251)

Here is an orchard in which are single apple trees, that have produced 3 hogsheads of cyder each; the diameter of the opposite boughs of one tree was measured, the extremities of which were 50 feet asunder, which, if considered as the diameter of a circle, the superficial content will be 1964 square feet, or 218 square yards, which is the quantity of ground that this tree covers; and if we suppose that a horse when standing, takes up the space of ground equal to 3 square yards, then there may stand no less than 72 horses under the drip of this apple tree.

An apple tree at Ballygamboon, Co. Kerry, described by Seward (1795)

Selection and note by Ben Simon,
Forest of Belfast Urban Forestry Initiative,
4-10 Linenhall Street, Belfast

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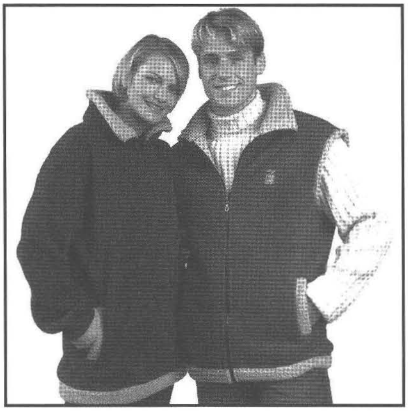

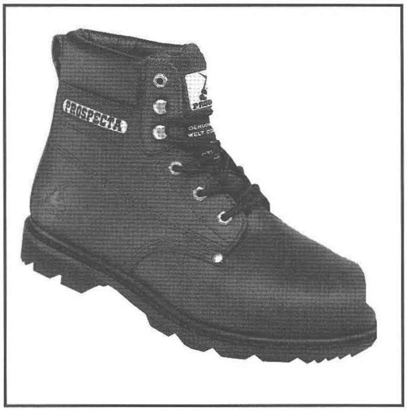
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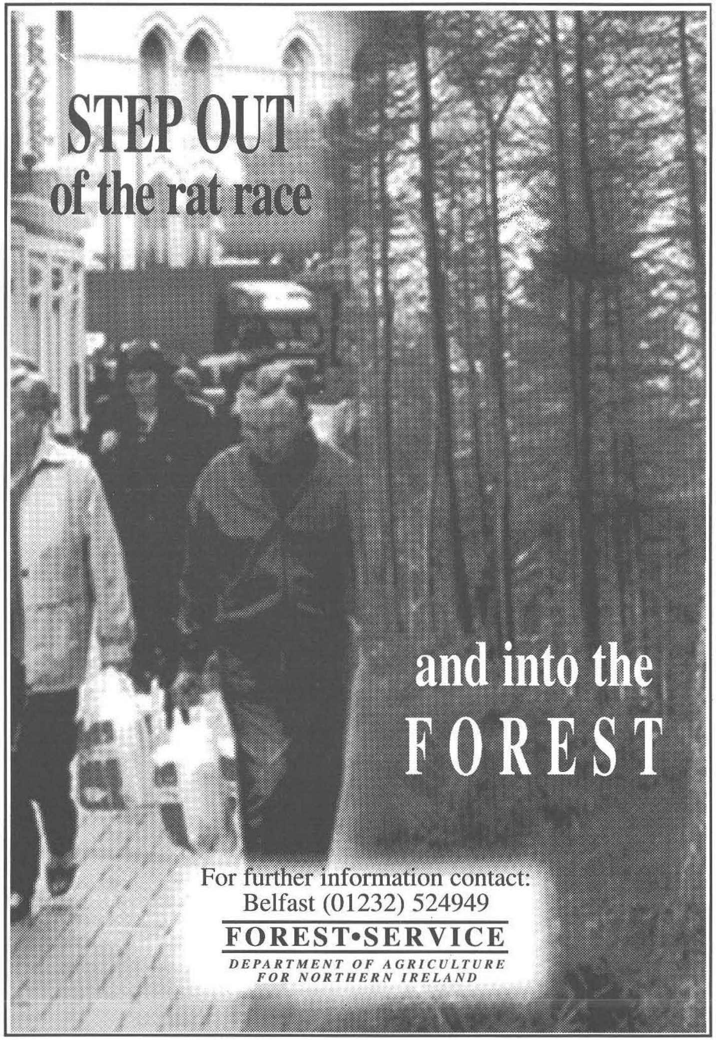
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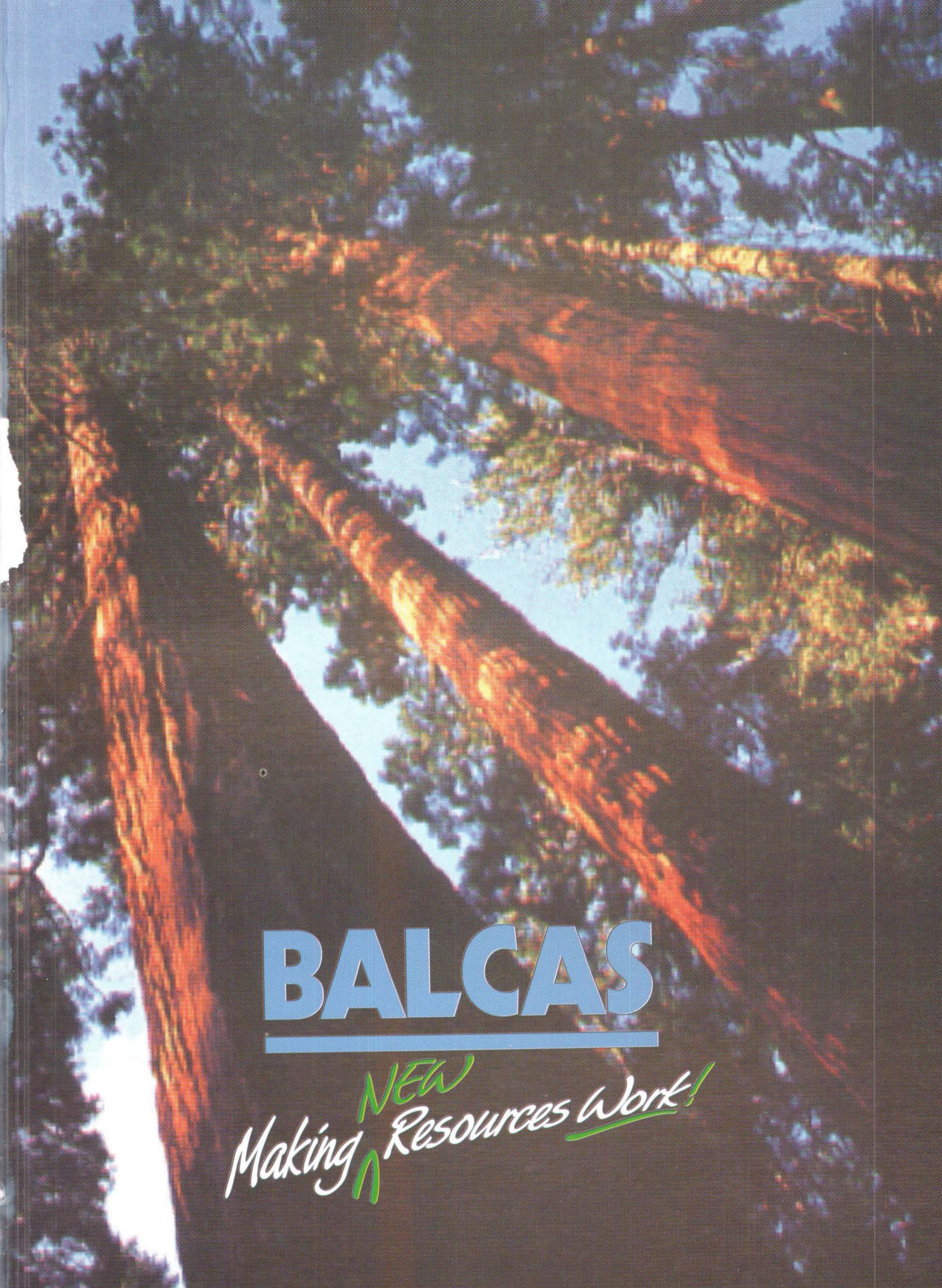
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